IMPERIAL INSTITUTE HANDBOOKS

RUBBER

ITS SOURCES, CULTIVATION, AND PREPARATION

BY HAROLD BROWN

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WITH A PREFACE BY

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WITH ILLUSTRATIONS

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PREFACE

In the present book Mr. Harold Brown gives a succinct and, within the limits of such a volume, a full account of the present position of the production of rubber, with particular reference to West Africa. Although *Hevea brasiliensis*, the Para rubber tree, holds a predominant position as a source of rubber and considerable attention is naturally given to it in this book, the other principal rubber-producing trees, Funtumia, Manihot, Castilloa, and Ficus, are all dealt with in some detail, as are also the Landolphia vines and other minor sources of the material.

As regards the prospects of rubber-growing in West Africa, apart from the indigenous Funtumia, it will be seen that the introduction of *Hevea brasiliensis* has been attended with success in the Gold Coast and in Southern Nigeria. Several samples of sheet rubber obtained from Hevea plantations in Southern Nigeria have been recently examined at the Imperial Institute and found to be equal in quality to the best plantation Para from the East.

The book is written partly for the student and partly for the planter, manufacturer, and merchant. The characteristics of the trees and the principal features connected with their natural occurrence and their cultivation in plantations are therefore included, as well as the more technical questions connected with the tapping, the collection and the preparation of rubber.

In dealing with the various aspects of the rubber-

producing industry, Mr. Brown brings to the task the knowledge gained by over ten years' continuous study of the subject, and the special advantage of possessing both botanical and chemical qualifications for the work.

The successful production of Para rubber in South America is more than two centuries old, and it is still mainly conducted on the most primitive lines and with the wild trees of the forest, which are of great age. So far as the actual preparation of rubber is concerned, these primitive methods have succeeded in placing on the market a material which is on the whole well suited to the requirements of the manufacturer, so much so that "fine hard Para" obtained from the wild trees of South America is still the market standard of the material.

As is the case with nearly every material obtained from wild and naturally distributed plants, as soon as the demand for the substance is large, it is necessary, chiefly for convenience of collection, to grow it in plantations, and the modern industry of rubber production involves the successful management of trees grown on the plantation system. In this sense rubber-growing is a new industry, as to which there is little or no previous experience to guide, and therefore the problem of the successful growth of forest trees under plantation conditions has to be solved by the use of the scientific methods of observation and investigation.

The proper methods of growing and manuring, the best times and methods of tapping, the nature of the parasitic and insect attacks to which trees in plantations are subject, have all had to be discovered, and on these subjects there is little or nothing to be learnt from previous forest experience.

Although the primitive methods of curing and preparing rubber from the latex practised in South America are eminently successful, it cannot be doubted that these methods are capable of simplification and also of improvement. Rubber as hitherto known to the manufacturer is a mixture containing many other ingredients than the true caoutchouc of the chemist. To a large extent it is still a matter of doubt as to what is the beneficial influence, if any, of the proteins, the resin, and the other companions of caoutchouc on the physical properties of the material. Moreover the exact nature

of what is included in the ordinary analysis as "caoutchouc" requires detailed examination. Crude rubber, moreover, is not the form in which the material is chiefly employed for manufacturing purposes, and the influence of the constituents other than caoutchouc on the properties of vulcanised rubber has yet to be definitely ascertained.

The plantation rubber industry, therefore, stands to gain everything from scientific research on these many different problems, which are well presented and discussed in the present volume.

The management of rubber plantations has become one of the most important branches of tropical agriculture, a subject which depends for its advancement on the application to its needs of several sciences of which chemistry and botany are two of the most important. The effective technical training of men who shall be capable of taking up work in tropical agriculture is one of the most urgent questions connected with the advancement of our tropical colonies, and I have referred to it at length elsewhere (see letter to *The Times*, April 29, 1913). A system of technical education in tropical agriculture is urgently called for, which shall not be less effective than that which is now undergone by professed agriculturists in Europe and the United States. In the provision of agricultural education in this country we have made great strides in recent years, but the organisation of education in tropical agriculture remains to be provided.

In conclusion, I may refer to the subject of "synthetic rubber," which is briefly discussed in one section of this book. As I pointed out in 1906,* when the question first came prominently before the public, the preparation on a large scale by chemical means of caoutchouc, identical with that produced by the tree, is well within the range of the modern chemist. The real question at issue is whether a satisfactory material can be manufactured cheaply enough to become a serious competitor with the natural product. This may well be doubted in view of the reduction in the cost of natural production which is now in progress, a reduction which will be accompanied by a decrease in the price of the raw material.

* "Address to the British Association," 1906. *Bulletin of the Imperial Institute*, 1906, p. 310, and 1909, p. 318.

There is a strong probability in favour of the view that when plantation rubber can be profitably sold at less than two shillings a pound, the plantation industry will be able to compete successfully with all kinds of forest rubber and will have little to fear from the competition of the synthetic material.

WYNDHAM R. DUNSTAN.

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RUBBER

CHAPTER I

INTRODUCTION

Historical.—Rubber, Indiarubber, or Caoutchouc is the elastic substance obtained by coagulating the latex of certain plants which occur throughout the tropics and are especially abundant in Central and South America and in Central Africa. The latex is a milk-like fluid which is usually obtained from the plants by making incisions in the bark.

On the discovery of the New World it was found that the natives of Central and South America were already familiar with the elastic nature of rubber and its property of rendering articles waterproof, and the records of the early voyages to that continent contain the first references to the product.

The first systematic study of the rubber plants of South America was made by Charles-Marie de La Condamine, the leader of the French expedition which went out to Ecuador in 1735 for the purpose of measuring a degree of the meridian. In 1736 La Condamine forwarded specimens of rubber to the French Academy of Sciences with a note stating that the product was obtained in the province of Esmeraldas (Ecuador) from a tree known by the natives as "hhévé." The Indians in Ecuador and Peru called the elastic substance "cahuchu" or "caucho," and from these names the word "caoutchouc" was derived. Fifteen years later La Condamine contributed a detailed

paper on the subject to the Mémoires of the Academy, and at the same time he forwarded to the Academy a paper by a French engineer named Fresnau, recording the discovery in French Guiana of another rubber-yielding tree, which was described by Fuset-Aublet in 1762 and named *Hevea guianensis.*

The principal rubber tree of South America and of the world, the tree which furnishes the Para rubber of commerce, is also a species of Hevea, and was first described by J. Müller as *Hevea brasiliensis* (*Linnaea*, vol. xxxiv. 1865–6). The source of the Ceara or Maniçoba rubber of Brazil was not determined until a later date, the first description of the tree being given in 1874 by Müller, who named it *Manihot Glaziovii*, after its discoverer Dr. Glaziov (Martius's *Flora Brasiliensis*, xi. part ii. p. 443).

The Central American rubber tree (*Castilloa elastica*) was first described in 1794 by Cervantes, who published an account of it with an engraved plate in the Mexican publication *Suplemento a la Gaceta de Literatura.* Cervantes named the tree *Castilla elastica*, but the generic name became subsequently changed to Castilloa, and the latter form is almost universally adopted at the present time.

The first rubber-yielding plant recorded from Asia was a vine discovered in 1798 by Dr. J. Howison on Prince of Wales Island off the coast of Malacca, which is believed to have been the plant afterwards described by Roxburgh as *Urceola elastica.* In 1810 Roxburgh was enabled by the services of Mr. M. R. Smith of Sylhet to establish the occurrence of a rubber-yielding tree in Assam, which he subsequently described and named *Ficus elastica.*

The rubber resources of Africa were not exploited until a much later date than those of America and Asia, for although Palisot de Beauvois described the vine *Landolphia owariensis* from West Africa in 1804, it was not until about fifty years later that the value of this plant and the allied vines as sources of rubber was realised. In 1817 Poiret described a rubber-yielding plant of Madagascar which he named *Vahea gummifera* (now known as *Landolphia madagascariensis*, K. Schum.), but in this case also no commercial development occurred

until after 1850. The discovery of the important West African rubber tree *Funtumia elastica*, Stapf (also known as *Kickxia elastica*, Preuss), is of very recent date, as it was first found in the Cameroons by Dr. Preuss in 1898. The rubber from this tree had been previously attributed to the allied species *Funtumia africana*, Stapf (*Kickxia africana*, Benth.).

Utilisation of Rubber.—The earliest use of rubber was made by the natives of Central and South America, who employed the latex for rendering boots and fabrics waterproof and for the manufacture of vessels of different kinds. For many years after its discovery caoutchouc was regarded in Europe merely as a curiosity, but in 1770 Priestley suggested that it might be employed for erasing pencil marks from paper, a use which led to the adoption of the name indiarubber for the product. Its first important industrial application was the process invented by Macintosh in 1820 for the production of waterproof fabrics; but it was the discovery, in 1839, of the process of vulcanisation by Goodyear in America which laid the foundation of the modern rubber industry. Goodyear found that if rubber is heated with sulphur, a change takes place, with the result that the material afterwards retains its elasticity through a much wider range of temperature than before. He subsequently discovered that the final effect of this treatment of rubber with sulphur was the production of the hard material known as ebonite or vulcanite. Specimens of vulcanised rubber prepared by Goodyear were brought to England in 1842, and Hancock, after seeing these, discovered independently that the change could be produced by heating a mixture of rubber and sulphur, or by immersing rubber in molten sulphur. These discoveries were of the highest importance, as they rendered it possible to utilise rubber for a large number of technical purposes for which the unvulcanised product was unsuitable, and as a result the use of rubber has steadily extended. During recent years the rubber manufacturing industry has assumed very large proportions, principally on account of the enormous demand for tyres for motor-cars, carriages, and cycles.

Cultivation of Rubber Plants.—Until recently rubber was obtained exclusively from wild plants growing in

the forests of tropical America, Africa, and Asia, about half of the total supply coming from the Amazon valley. In consequence, however, of the increasing demand for rubber and the possibility of a diminution in the supply, owing to the destruction of large numbers of the wild rubber-yielding plants, considerable attention has been devoted during the last ten years to the cultivation of rubber trees in almost all tropical countries, with the result that rubber planting is now one of the most important tropical industries.

The Para rubber tree (*Hevea brasiliensis*) from the Amazon valley has proved to be very suitable for general cultivation throughout the tropics, and it is now being grown on a very large scale in the Malay Peninsula, Ceylon, Sumatra, and Java, and to a smaller extent in Southern India and Burma, and in Borneo. The Para tree is also being cultivated in tropical Africa, including many of the British Colonies and Protectorates in East and West Africa, in Seychelles, in British Guiana, in the West Indies, and in some of the islands of the Pacific; in many of these countries the tree has given very promising results. Plantations of the Para tree have also been formed in Brazil.

The Ceara rubber tree (*Manihot Glaziovii*), also a native of Brazil, has been introduced into nearly every tropical country. It offers the advantages that it is very hardy and can be grown in dry situations where the Para tree will not thrive, but it is more difficult to tap successfully than the latter. The Ceara tree is at present being cultivated extensively in British and German East Africa, Uganda, and Nyasaland, where it promises to do well, and is also grown in Ceylon and Southern India.

In Africa large plantations of the indigenous rubber tree (*Funtumia elastica*) have also been formed in several countries; and in Central America and the West Indies the Central American rubber tree (*Castilloa elastica*) is being cultivated on an extensive scale.

Recent estimates of the area of the rubber plantations throughout the tropics have given various totals up to two million acres, but the figures for many of the countries are admittedly only approximations. The following statistics of the acreages under rubber during

the years 1901 to 1912 in Ceylon and Malaya (the Straits Settlements and the Malay States) will show the development which has occurred in the rubber-planting industry in these countries:

	Ceylon. acres.	Malaya. acres.
1901	2,500	—
1902	4,500	—
1903	7,500	—
1904	11,000	—
1905	40,000	50,000
1906	100,000	99,230
1907	150,000	179,227
1908	175,000	241,138
1909	180,000	292,035
1910	200,000	362,853
1911	215,000	542,877
1912	230,000	621,621

The total of 621,621 acres planted with rubber in Malaya at the end of 1912 was made up as follows: Federated Malay States, 399,197 acres; Straits Settlements, 94,263 acres; and the unfederated States of Johore, Kedah, Kelantan, and Trengganu, 128,161 acres.

The following recent figures, giving the acreages under rubber in various other countries, may also be quoted: Java, 230,000; Sumatra, 160,000; Southern India and Burma, 45,000; British North Borneo, 25,600; Papua, 4,500; German New Guinea, 6,000; Nyasaland, 8,896; East Africa Protectorate, 3,000; Uganda, 3,860; German East Africa, 60,000; Cameroons, 17,500; British Guiana, 2,250. Large plantations of rubber trees have also been formed in British West Africa, French West Africa, the Belgian Congo, Mexico, and Central America, but definite figures regarding the acreages are not available.

World's Production of Rubber.—The estimated world's production of rubber during the last six years is given in the following table, which also shows the amount of plantation rubber from Ceylon and Malaya included in the total:

	World's total supply.*	Plantation rubber from Ceylon and Malaya.
	Tons.	Tons.
1907	69,000	1,130
1908	70,000	2,040
1909	75,000	4,000
1910	80,000	8,100
1911	85,000	14,310
1912	96,000	25,650

Previous to the large increase in the production of plantation rubber which has occurred during the last few years, more than half of the world's supply of rubber was obtained from wild Para trees in the Amazon valley, and the amount furnished by Central and South America was more than three-fifths of the total. Africa contributed about one-third and Asia about one-fifteenth of the supply. Latterly, however, the Asiatic production has been very considerably increased by the rubber from the plantations, which amounted in 1910 to about 8,000 tons or one-tenth of the world's supply, in 1911 to about 14,000 tons or one-sixth of the world's supply, and in 1912 to about 25,600 tons or more than one-fourth of the world's supply.

The production of plantation rubber will show a very rapid increase during the next few years as the estates already established reach the tapping stage, and there is little doubt that the rubber from cultivated trees will soon form a very large part of the total supply.

Rubber Production in America.—The total exports of rubber of all kinds from Brazil since 1903 are shown in the following table:

	Metric Tons.		Metric Tons.
1903	31,712	1908	38,206
1904	31,863	1909	39,020
1905	35,392	1910	38,546
1906	34,960	1911	36,547
1907	36,489	1912	42,285

The quantities of the different kinds of rubber

* Messrs. Lewis & Peat's estimates.

included in the above totals for the years 1903 to 1909 are given in the table on this page.

The total production of rubber in Brazil showed a gradual increase from 31,712 metric tons in 1903 to 39,020 metric tons in 1909; during the next two years there was a slight decline, followed in 1912 by a considerable rise to 42,285 metric tons. Para rubber forms the main portion of the exports, but there has been a large increase recently in the production of Caucho rubber (Castilloa), which in 1910 amounted to over 8,000 metric tons. Brazil possesses large reserves of Para trees which have hitherto remained unexploited on account of difficulties of labour and transport, but some of these areas will be opened up in the immediate future.

The principal rubber-producing countries in America, other than Brazil, are Mexico, Peru, and Bolivia. Some of the rubber obtained in Peru and Bolivia is brought down the Amazon for shipment, and is therefore included in the exports from Brazil. The following statistics show the quantities of rubber exported from Mexico, Peru, and Bolivia during recent years:

Local Name.	Variety of rubber.	1903.	1904.	1905.	1906.	1907.	1908.	1909.
		Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Seringa fina	Para rubber *Hevea brasiliensis*	25,828	24,873	26,749	26,707	27,787	28,963	
Seringa sernamby		260	287	598	280	480	692	
Seringa (not specified)	—							35,404
Seringa Caucho	Castilloa rubber, *C. Ulei*	3,240	3,632	4,726	4,656	5,115	6,040	
Manigoba	Ceara rubber, *Manihot Glaziovii*	1,722	2,216	2,682	2,664	2,429	2,166	3,106
Mangabeira	Hancornia rubber, *H. speciosa*	662	855	637	653	678	345	510
GRAND TOTAL		31,712	31,863	35,392	34,960	36,489	38,206	39,020

Exports of Rubber from Mexico

Year.	Metric tons.	Year.	Metric tons.
1905–6	1,450	1908–9	6,015
1906–7	4,691	1909–10	8,068
1907–8	5,624	1910–11	7,429

Exports of Rubber from Peru

Year.	Metric tons.	Year.	Metric tons.
1905	2,539	1908	2,516
1906	2,575	1909	2,802
1907	3,027		

Exports of Rubber from Bolivia

Year.	Metric tons.	Year.	Metric tons.
1905	1,677	1908	2,607
1906	1,930	1909	3,052
1907	1,830	1910	3,118

Rubber Production in Africa.—The production of rubber in Africa during the years 1909 and 1910 is given in the following table taken from the *Indiarubber Journal* (December 30, 1911):

	1909. Tons.	1910. Tons.
British Possessions	1,974	2,818
French Possessions	6,647	7,340
German Possessions	2,114	2,800
Belgian Possessions	5,217	5,000
Portuguese Possessions	3,161	3,504
Totals	19,113	21,462

In these two years, therefore, the rubber obtained from Africa amounted to a little more than one-fourth of the estimated world's supply.

The bulk of the African rubber comes from French and Belgian possessions, which together furnished more than one-half of the total in 1909 and 1910, whilst the contribution of the British possessions was about one-tenth of the total in 1909 and a little over one-eighth in 1910. It will be noticed that all the countries showed an increased production during 1910, with the exception of the Belgian Congo.

Rubber Production in Asia.—The amount of wild rubber collected in Asia is comparatively small, and it is the large increase in the production of plantation rubber which has made this continent of importance as a source of supply.

The following statement gives the exports of plantation rubber from Ceylon and Malaya since 1903:

	Ceylon. Tons.	Malaya. Tons.
1903	19	—
1904	35	—
1905	75	130
1906	146	430
1907	248	885
1908	407	1,629
1909	666	3,340
1910	1,601	6,504
1911	3,194	11,118
1912	6,697	18,956

These figures show the remarkable development which has taken place in the rubber-planting industry in Ceylon and Malaya during recent years. The total production of plantation rubber in these countries rose from about 200 tons in 1905 to no less than 25,653 tons (equal to more than one-fourth of the world's supply) in 1912, and the output will increase considerably in the immediate future. In addition, large quantities of rubber will be obtained from the plantations which have been established in India, Java, Sumatra, and Borneo.

Rubber Produced in the British Empire.—The contribution of the British Empire to the world's supply of rubber is shown in the table on page 10, which gives the production in the various Colonies and Protectorates and in the dependent and protected States and Territories during the six years 1906 to 1911.

It will be seen from these figures that, owing to the development of the rubber plantations in Ceylon and Malaya, the contribution of the British Empire to the world's supply of rubber has increased from 4,687 tons in 1906 (less than one-thirteenth of the total) to 16,362 tons in 1911 (nearly one-fifth of the total). The returns for 1912 will show another large increase.

I.—Rubber produced in the Crown Colonies, Possessions, and Protectorates

	1906.	1907.	1908.	1909.	1910.	1911.
	lb.	lb.	lb.	lb.	lb.	lb.
British India *	502,768	334,880	219,968	180,432	435,120	1,002,512
Ceylon	414,960	794,416	1,146,656	1,741,488	3,802,624	6,855,709
Straits Settlement	25,560	105,621	145,580	783,694	1,261,745	3,136,841
Papua †	7,446	10,144	4,000	1,278	4,225	9,601
Gambia	10,454	61,405	18,568	15,548	7,148	10,733
Sierra Leone	240,049	164,463	92,016	57,641	47,287	41,443
Gold Coast	3,649,668	3,549,548	1,773,248	2,764,190	3,223,265	2,668,667
Southern Nigeria ‡	3,434,279	2,843,823	1,222,203	1,388,009	2,634,023	2,164,286
Uganda *	73,191	34,530	47,738	105,909	101,352	45,923
East Africa Protectorate *	148,624	118,160	81,424	177,184	193,312	135,184
Nyasaland *	16,403	15,533	15,415	27,144	59,472	47,709
British Guiana *	2,563	6,873	5,751	6,369	1,156	3,104
British Honduras	20,244	24,112	25,380	17,163	14,974	21,362
Trinidad and Tobago	1,067*	4,444*	2,146*	13,234	7,376	2,033
Jamaica	—	—	948	130	128	—
Total lb.	8,547,276	8,067,952	4,801,041	7,279,413	11,793,207	16,145,107

II.—Rubber produced in the Dependent and Protected States and Territories

	1906.	1907.	1908.	1909.	1910.	1911.
Federated Malay States	1,178,530	2,169,691	3,247,197	6,167,200	12,301,811	19,834,177§
British North Borneo	144,000	224,400	86,267	116,800	161,333	260,933
Sarawak	628,267	577,733	429,467	414,533	347,333	410,267
Zanzibar and Pemba	2,955	988	1,334	2,740	4,124	4,285
Total lb.	1,953,752	2,972,812	3,764,265	6,701,273	12,814,601	20,509,662
Grand Total for British Empire. lb.	10,501,028	11,040,764	8,565,306	13,980,686	24,607,808	36,654,769
,, ,, ,, Tons	4,688	4,929	3,824	6,241	10,986	16,364
Estimated World's Production Tons	65,000	69,000	70,000	75,000	80,000	85,000

* For the 12 months ended March 31 of the years following those stated.
† For the 12 months ended June 30 of the year stated.
‡ Including the exports from Northern Nigeria.
§ Including 138,933 lb. from the Protected Malay States.

CHAPTER II

RUBBER IN BRITISH AFRICA

Before dealing in detail with the principal rubber-yielding plants, it is proposed to give in the present chapter a general account of the rubber industry in the British Colonies and Protectorates in Africa, including particulars of the indigenous rubber plants and of the present position of rubber cultivation in each country.

BRITISH WEST AFRICA: GAMBIA, SIERRA LEONE, GOLD COAST, AND NIGERIA

Rubber is one of the most important natural products of the British Colonies and Protectorates in West Africa. The quantity exported from the Gambia and Sierra Leone has, however, diminished very considerably during recent years, and at present the supply is chiefly obtained from the Gold Coast and Nigeria. The quantities and values of the exports of rubber during the years 1901 to 1912 from each of the countries are given in the following tables:

Quantities.

<table>
<tr><th rowspan="2">Year.</th><th rowspan="2">Gambia.</th><th rowspan="2">Sierra Leone.</th><th rowspan="2">Gold Coast.</th><th colspan="2">Southern Nigeria.</th></tr>
<tr><th>Colony (Lagos).</th><th>Protectorate.</th></tr>
<tr><td></td><td>lb.</td><td>lb.</td><td>lb.</td><td>lb.</td><td>lb.</td></tr>
<tr><td>1901 . .</td><td>146,573</td><td>131,600</td><td>1,520,009</td><td>194,280</td><td>1,740,156</td></tr>
<tr><td>1902 . .</td><td>65,283</td><td>103,783</td><td>1,599,974</td><td>151,440</td><td>865,834</td></tr>
<tr><td>1903 . .</td><td>19,551</td><td>106,648</td><td>2,258,981</td><td>131,311</td><td>1,177,803</td></tr>
<tr><td>1904 . .</td><td>30,934</td><td>152,219</td><td>4,013,837</td><td>265,458</td><td>2,408,926</td></tr>
<tr><td>1905 . .</td><td>9,071</td><td>426,610</td><td>3,687,778</td><td>271,904</td><td>2,842,831</td></tr>
<tr><td>1906 . .</td><td>10,454</td><td>240,049</td><td>3,649,668</td><td colspan="2">3,434,279</td></tr>
<tr><td>1907 . .</td><td>61,405</td><td>164,463</td><td>3,549,548</td><td colspan="2">2,843,823</td></tr>
<tr><td>1908 . .</td><td>18,568</td><td>92,016</td><td>1,773,248</td><td colspan="2">1,222,203</td></tr>
<tr><td>1909 . .</td><td>15,548</td><td>57,641</td><td>2,764,190</td><td colspan="2">1,388,009</td></tr>
<tr><td>1910 . .</td><td>7,148</td><td>47,287</td><td>3,223,265</td><td colspan="2">2,634,023</td></tr>
<tr><td>1911 . .</td><td>10,733</td><td>41,443</td><td>2,668,667</td><td colspan="2">2,164,286</td></tr>
<tr><td>1912 . .</td><td>4,335</td><td>21,970</td><td>1,990,699</td><td colspan="2">1,579,200</td></tr>
</table>

VALUES.

Year.	Gambia.	Sierra Leone.	Gold Coast.	Southern Nigeria.	
				Colony (Lagos).	Protectorate.
	£.	£.	£.	£.	£.
1901 . .	8,963	9,203	104,030	14,749	106,925
1902 . .	4,238	8,192	88,602	9,272	46,946
1903 . .	1,544	9,258	196,500	15,583	61,816
1904 . .	2,446	18,055	360,644	22,961	158,991
1905 . .	915	49,132	323,774	23,248	226,387
1906 . .	1,084	30,170	334,505	307,077	
1907 . .	5,686	22,480	333,120	244,989	
1908 . .	1,163	9,372	168,144	98,530	
1909 . .	1,550	8,079	263,694	109,076	
1910 . .	952	7,666	358,876	311,691	
1911 . .	836	5,918	219,447	179,355	
1912 . .	409	2,962	168,729	125,021	

The figures for Southern Nigeria include the exports from Northern Nigeria, which during the years 1907 to 1911 were as follows :

	lb.		lb.
1907 . .	1,187,588	1910 . .	519,943
1908 . .	511,110	1911 . .	752,569
1909 . .	449,345	1912 . .	451,300

The total exports of rubber from British West Africa during the years 1905 to 1911, as shown in detail above, are given in the following table :

	Quantity.	Value.
	Tons.	£.
1905	3,231	623,456
1906	3,274	672,836
1907	2,955	606,275
1908	1,387	277,209
1909	1,886	382,399
1910	2,639	679,185
1911	2,181	405,556

It will be seen from these figures that, notwithstanding some fluctuations in the contributions of the different countries, the total exports of rubber from British West Africa during the years 1905 to 1907 re-

mained approximately the same, viz. about 3,000 tons, which was a little less than 5 per cent. of the world's supply. The heavy decline to only 1,387 tons in 1908 was attributed mainly to the serious fall in the value of rubber, which checked the collection by the natives, and during the next two years the recovery in the price led to a considerable increase in the exports. The figures for 1910, when rubber realised the highest price it has ever reached, were, however, not equal to those of the years 1905 to 1907. During 1911 the price of rubber became normal again, and the total exports diminished to a little less than 2,200 tons, or about 2½ per cent. of the world's supply.

Considerable attention has been devoted to rubber during recent years by the Agricultural and Forestry Departments in British West Africa, with the objects (1) of preserving, as far as possible, the existing wild plants; (2) of improving the quality of the rubber by the introduction of new methods of preparation; and (3) of forming experimental plantations of indigenous or exotic rubber trees, and encouraging rubber cultivation by European planters and by the natives. It has been sought to attain the first two objects by instructing the natives in proper methods of tapping the plants and of preparing the rubber, and, in certain cases, by the introduction of regulations for controlling the industry.

The efforts which have been made to start the cultivation of rubber trees in British West Africa have been very successful, and large plantations have been already formed in the Gold Coast and Southern Nigeria. The trees which have been principally tried are the indigenous *Funtumia elastica* and the Para tree, *Hevea brasiliensis*. It has been proved that both of these trees can be successfully cultivated on a large scale in West Africa, but the general consensus of opinion is at present in favour of the Para tree wherever the conditions are suitable for its growth, as this tree promises to give a much larger annual yield of rubber than the Funtumia. The latter tree can, however, be grown in semi-dry districts where the Para tree will not thrive.

The following account gives a brief summary of the position of the rubber industry in each of the West African Colonies and Protectorates (see also *The Agri-*

cultural and Forest Products of British West Africa, by G. C. Dudgeon, in this series of Handbooks).

Gambia

The exports of rubber from this Colony reached their height in 1898, when they amounted to 481,020 lb., valued at £30,468. Since that date, however, there has been a very considerable decline in the exports, which have fluctuated in a very marked manner from year to year and in 1910 fell to 7,148 lb. valued at £952, and in 1912 to 4,335 lb. valued at £409. It is stated that, owing to the destruction of the vines by the natives, very little rubber has been collected in the Colony since 1905, and that a large part of the rubber exported has been obtained from the surrounding French territory. Recent legislation in the French Colonies will tend to diminish this transit trade, and there is therefore very little hope of any considerable increase in the exports of rubber from the Gambia in the future.

The principal indigenous rubber plant in the Gambia is the vine *Landolphia Heudelotii*, A.DC. This vine was most abundant in the Jolah country, but has been largely exterminated through excessive tapping. To obtain the rubber from the vines, the natives make incisions in the stems and sprinkle salt water on the cuts in order to accelerate the coagulation of the latex. After four or five hours the rubber is collected from the incisions, the strips being usually wound together to form balls.

Landolphia Heudelotii frequently occurs in the Gambia on grass lands subject to annual fires, where it develops a bushy form. The natives obtain rubber from these plants by exposing the roots and treating them in the manner described above for the stems.

In addition to *Landolphia Heudelotii*, the following vines have been recorded from the Gambia: *Landolphia florida*, Benth., *Landolphia senegalensis*, Kotschy and Peyr. (both of which yield resinous products of no value), and *Baissea multiflora*, A.DC.

Ficus Vogelii, Miq., also occurs in the Colony, but the rubber which it furnishes is of very resinous nature and is not at present collected by the natives.

No attempts have been made to cultivate rubber

trees in the Colony, although a number of exotic species have been introduced for trial. The Ceara tree (*Manihot Glaziovii*) has given the most promising results, but there is very little information on record regarding the yield of rubber furnished by the trees.

Sierra Leone

The figures of the exports of rubber from Sierra Leone show that the trade reached its maximum in 1891, when 1,496,432 lb. valued at £77,737 were shipped from the Colony. Subsequently there has been a considerable decline, and in 1912 the exports were only 21,970 lb. valued at £2,962. The chief reasons for this decrease in the exports are (1) the extermination of the wild plants in the Protectorate by improper methods of tapping; (2) the clearing of large areas of forest land by the natives for purposes of cultivation; and (3) the diversion into other channels of most of the rubber from the surrounding territories, and also of the rubber obtained in the Koinadugu district of the Protectorate, which no longer comes down to Freetown. The fall in the exports which occurred in 1908 was attributed principally to the very low price of rubber during that year, but the figures for 1909 to 1912 show a continued decline.

The rubber-yielding plants indigenous to Sierra Leone include species of Landolphia and Clitandra vines, which occur in all the districts of the Protectorate, and also the West African rubber tree, *Funtumia elastica*, Stapf, which was recently found in the forests of the Panguma district in the east of the Protectorate. The bulk of the rubber exported is stated to come from the Bandajuma, Panguma, and Koinadugu districts.

The most abundant rubber vine is known as "Jenje," and has been identified as *Landolphia owariensis*, Beauv., or as a variety of this species considered by Chevalier to be the plateau form of the plant. The rubber is collected by the natives in the following ways: (1) Incisions are made in the stem and the latex is coagulated by sprinkling lime-juice or a solution of salt on the cuts. The rubber is left on the stem for a short time, and is then stripped off and rolled into balls. (2) The vine is cut down and divided into pieces which are soaked

in water for several weeks; the bark is then stripped off and the rubber separated from it by beating and washing. The roots are also treated in a similar manner. The rubber thus obtained is cut into strips and wound into balls.

Another rubber-yielding vine, known as "Jawe," which occurs throughout the eastern part of the Protectorate, has been identified as a species of Clitandra, cf. *C. laxiflora*, Hallier f., whilst a false "Jawe" proves to be *Clitandra Mannii*, Stapf. From the former vine the latex is collected in bulk and coagulated by boiling.

The *Funtumia elastica* tree is known as "Gboigboi" in the Panguma district. To obtain the rubber, the natives usually felled the trees and tapped them by making annular incisions in the bark at frequent intervals. The latex was collected and heated in a pot over a fire, the freshly coagulated rubber being removed, placed between leaves on the ground, and stamped with the feet until it was pressed out into a cake; it was then cut into strips and wound into balls. The Funtumia rubber prepared in this way came into commerce under the name of "Manoh twist." Sometimes the natives stripped off the bark from the felled trees and extracted the rubber from it by a process of beating and washing. This practice of cutting down the trees is now being prevented as far as possible.

Ficus Vogelii, Miq., also occurs in Sierra Leone, and its latex is said to be used by the natives for mixing with that of *Funtumia elastica* and the rubber vines.

The cultivation of the indigenous *Funtumia elastica* has been undertaken on a small scale in Sierra Leone, but the trees are not yet old enough for tapping. Experiments with the Para tree (*Hevea brasiliensis*) are also in progress, small plantations of the trees having been established at a number of stations, and the results so far obtained are fairly promising.

Gold Coast

The production of rubber in the Gold Coast has shown less diminution than in the Gambia and Sierra Leone. The exports during the years 1890 to 1896 varied from 2¾ to 4 million lb.; a rise then took place and the

maximum was reached in 1898 when 5,984,984 lb. valued at £551,667 were shipped from the Colony. During the four years 1900 to 1903 there was a considerable falling-off, which was attributed principally to the disturbances in Ashanti, but from 1904 to 1907 the production again increased to 3½ to 4 million lb. per annum. The heavy decline in 1908, when the exports fell to 1,773,248 lb., was primarily due to the very low price of rubber, which made its collection less profitable to the natives, and not to any general failure of the supply. Consequently in 1909 the production again increased to 2,764,190 lb., and in 1910, when very high prices were realised, there was a further increase to 3,223,265 lb. Since then, however, the exports have again diminished, and in 1912 they were only 1,990,699 lb. valued at £168,729.

The principal rubber-yielding plants indigenous to the Gold Coast are *Funtumia elastica*, Stapf, *Landolphia owariensis*, Beauv., and *Ficus Vogelii*, Miq.; in addition *Landolphia Klainei*, Pierre, *Landolphia Thompsonii*, Chev., and other vines also occur. The rubber is chiefly collected in the forests of Ashanti, Sefwi, and Akim, some of which are very rich in rubber-yielding plants.

In tapping *Funtumia elastica* the natives employ the double herringbone system (see p. 66) and the incisions are carried as high up the tree as possible, often to a height of 50 ft. or more. The latex is collected at the foot of the tree in a vessel into which it is directed by a clay lip, or by a piece of wood or leaf inserted in the bark. It is usually poured, without being strained, into a shallow oblong pit, dug in the ground and carefully plastered with clay in order to render it partially water-tight, and is allowed to remain there for a considerable time until coagulation has taken place and the rubber is sufficiently firm to be removed. The product thus obtained is a porous mass of rubber containing a large quantity of the serum of the latex, and therefore very liable to ferment and develop objectionable odours. Sometimes the acid juice of limes or other fruits, or more rarely a solution of salt, is added to effect coagulation, or the latex is boiled.

The value of the Gold Coast "lump" rubber is depreciated not only by the method adopted for its pre-

paration, but also by the native practice of adding to the latex of *Funtumia elastica* before coagulation the latices of non-rubber-yielding plants, such as *Funtumia africana*, Stapf, *Chlorophora excelsa*, Bth. and Hook. f., *Antiaris toxicaria*, Lesch., *Alstonia* sp., etc., which render the rubber resinous and adversely affect its physical properties. In consequence of this procedure Gold Coast "lump" is usually of inferior quality and realises a comparatively low price in the market.

Attempts are being made to induce the natives to keep the latex of *Funtumia elastica* pure, and to coagulate it by boiling the diluted latex or by adding to the latex a hot infusion of *Bauhinia reticulata* leaves or a quantity of the juice of the Diecha vine, *Strophanthus Preussii*. The freshly coagulated rubber is then rolled out into biscuits.

The rubber of *Landolphia owariensis* is usually collected in the form of balls, and is of very good quality. This vine has also been found to occur in the Northern Territories of the Gold Coast, where it is known as "Pempeneh," but it does not appear to be very abundant there.

An inferior "flake" or "paste" rubber, which is of very resinous character, is also prepared from the latices of certain vines.

Ficus Vogelii is freely distributed in certain parts of the Gold Coast, but the tree is not usually tapped by the natives. The rubber is of very resinous character, like that obtained from the tree in the Gambia.

Considerable progress has been made in the cultivation of rubber trees in the Gold Coast. *Hevea brasiliensis*, the Para tree, was first introduced into the Botanic Gardens at Aburi, and Government plantations of the trees have since been established at Tarquah, Coomassie, and Assuantsi. The cultivation of this tree has also been undertaken by European planters, and large numbers of the seeds and seedlings have been distributed to the natives in different districts. In 1911 three of the European planting companies had each from 40,000 to 60,000 Para trees of various ages on their estates. The results of experimental tappings on both Government and private plantations have been very promising.

Similar action has been taken with regard to the indigenous *Funtumia elastica*, plantations of which have been established by the Government, by planters, and

by the natives. Two planting companies had each about 40,000 Funtumia trees under cultivation in 1911.

Experiments have also been made with the Central American rubber tree (*Castilloa elastica*), the Ceara tree (*Manihot Glaziovii*), and the Assam rubber tree (*Ficus elastica*), but none of these has given very promising results up to the present. Some of the new species of Manihot are also being cultivated experimentally.

Southern Nigeria

Since 1906 the old Colony and Protectorate of Lagos has been included in the Colony and Protectorate of Southern Nigeria, of which it forms the Western Province.

The rapid development of the rubber resources of Lagos, following the discovery in the country of a rubber-yielding tree (subsequently identified as *Funtumia elastica*), forms one of the most remarkable events in connection with the West African rubber trade. In 1894 the exports were only 5,867 lb. valued at £324, but in the following year they jumped to no less than 5,069,576 lb. valued at £269,893, and the maximum production was reached in 1896, when the figures were 6,484,365 lb. and £347,721 respectively. This enormous increase in the production was obtained by destructive methods of tapping, which are stated to have killed 75 per cent. of the trees, and was followed by a rapid decline, the exports falling to 596,332 lb. in 1900 and 131,311 lb. in 1903. Some recovery took place subsequently, and in 1906 the production of rubber in Lagos was 927,627 lb. valued at £91,260.

In the old Protectorate of Southern Nigeria (the Eastern and Central Provinces of the new administration) the variation in the supply of rubber has not been so extreme. The exports were 874,298 lb. in 1898–9 and increased to 2,251,315 lb. in 1900; during the next two years they declined, the figures for 1902 being 865,834 lb., but subsequently they again increased, and in 1905, the last year of the old administration, the exports of rubber were 2,842,831 lb. valued at £226,387, the highest figures attained.

The exports from the whole of the new Colony and Protectorate of Southern Nigeria declined considerably during the years 1906 to 1909, the figures being 3,434,279 lb. in 1906; 2,843,823 lb. in 1907; 1,222,203 lb. in 1908;

and 1,388,009 lb. in 1909. The diminution in 1907 was stated to be due to the prohibition of tapping in some of the principal rubber districts, whilst the low price of rubber in 1908 no doubt adversely affected the production in that year. During 1910 the exports increased to 2,634,023 lb., nearly double those of the previous year, whilst in 1911 and 1912 they were 2,164,286 lb. and 1,579,200 lb. respectively.

It must be remembered that the exports of rubber from Southern Nigeria include the amount obtained in Northern Nigeria, which forms a considerable percentage of the total (see p. 12).

The indigenous rubber-yielding plants of Southern Nigeria are *Funtumia elastica* and species of Landolphia, Clitandra, and Carpodinus vines.

The Funtumia rubber is usually prepared in the form of "lump" by methods similar to those employed in the Gold Coast, which have been already described, and the product suffers from the same defects.

Persistent efforts are being made by the Forestry Department to induce the natives to adopt improved methods of tapping the trees, to abandon the practice of mixing inferior latices with that of *Funtumia elastica*, and to prepare the unadulterated rubber in biscuit form.

The most important of the rubber-yielding vines indigenous to Southern Nigeria are *Landolphia owariensis* and *Clitandra elastica*, Chev., both of which furnish good rubber, which is usually collected in the form of balls. *Landolphia Thompsonii* and two species of Carpodinus, *C. hirsuta*, Hua, and *C. fulva*, Pierre, also occur and yield the inferior product known as "flake rubber." *Ficus Vogelii* is found in Lagos, but does not appear to be tapped regularly by the natives.

The question of rubber cultivation has received considerable attention in Southern Nigeria. Government plantations of *Funtumia elastica* have been established, and the natives have been encouraged to plant these trees in considerable numbers in proximity to their villages. Many of these native plantations are now reaching the producing stage, and the rubber obtained in the first tapping experiments on a large scale has been sold in London at very good prices.

Similar action has been taken with the Para tree,

which has been successfully introduced and found to grow well in parts of the wet zone. A number of European companies have already formed plantations of Para trees, the largest of which are in the Sapele district, where two estates had respectively 70,000 and 20,000 trees of various ages in 1911. The results of the experimental tappings have been exceedingly promising.

Other exotic rubber trees, such as *Castilloa elastica*, *Manihot Glaziovii*, and *Ficus elastica*, are also being grown experimentally in Southern Nigeria.

Northern Nigeria

The rubber collected in Northern Nigeria passes in transit through Southern Nigeria and is included in the exports from the latter country. The separate returns of the exports of rubber from Northern Nigeria have only been given during recent years, and are as follows: 511,110 lb. in 1908; 449,345 lb. in 1909; 519,943 lb. in 1910; 752,569 lb. in 1911; and 451,300 lb. in 1912.

The rubber-yielding plants of Northern Nigeria are the same as those occurring in Southern Nigeria, and are chiefly found in the south of the Protectorate in the Provinces of Kabba, Bassa, Nassarawa, and Ilorin. The rubber is prepared in similar ways to those in use in Southern Nigeria. A considerable quantity of "root rubber" is made in Northern Nigeria by beating the bark of the roots and stems of vines, and is known as "brown cluster" or "brown medium."

An inferior product known as "paste" rubber is also prepared in Northern Nigeria by mixing the latex of the "Ebo" or "Ibo" vine (*Landolphia florida*) with an equal quantity of the wood oil obtained from *Daniella thurifera*. The liquid is then boiled and kept constantly in motion by stirring until it forms a sticky mass which can be handled in water without adhering to the skin. This "paste" rubber is exported in casks.

The rubber of *Ficus Vogelii* is exported under the name "balata," the product being of inferior quality owing to the large percentage of resin present.

Other species of Ficus, such as *Ficus platyphylla*, Del., furnish the product known locally as "red Kano rubber." It is a hard resinous material, exhibiting some resemblance to gutta percha in its properties.

The cultivation of rubber trees is being tried experimentally in Northern Nigeria. Small plantations of *Funtumia elastica* trees have been formed near Lokoja and Zungeru and also in the Bassa Province. Trials are also being made with Para and Ceara trees, and the latter have given very promising results.

UGANDA, EAST AFRICA PROTECTORATE, AND NYASALAND

The exports of rubber from the three British Protectorates in East Africa are very much smaller than those from British West Africa, as will be seen by comparing the following tables, giving the figures for the years 1900–1 to 1912–13, with those on pp. 11 and 12.

QUANTITIES

	Uganda.	East Africa Protectorate.	Nyasaland.
	lb.	lb.	lb.
1900–1 . . .	—	100,600	86,404
1901–2 . . .	—	cannot be stated	14,393
1902–3 . . .	68,626	,, ,,	11,723
1903–4 . . .	45,809	96,948	4,372
1904–5 . . .	51,970	182,863	17,664
1905–6 . . .	42,718	144,032	17,280
1906–7 . . .	73,191	148,624	16,403
1907–8 . . .	34,530	118,160	15,533
1908–9 . . .	47,738	81,424	15,415
1909–10 . . .	105,909	177,184	27,144
1910–11 . . .	101,352	193,312	59,472
1911–12 . . .	45,923	135,184	47,709
1912–13 . . .	—	—	61,112

VALUES

	Uganda.	East Africa Protectorate.	Nyasaland.
	£	£	£
1900–1 . . .	—	10,060	9,332
1901–2 . . .	—	5,112	1,626
1902–3 . . .	3,431	7,778	1,180
1903–4 . . .	2,795	10,772	426
1904–5 . . .	3,465	21,579	2,208
1905–6 . . .	5,695	18,929	2,160
1906–7 . . .	9,759	19,944	3,486
1907–8 . . .	4,603	14,402	3,300
1908–9 . . .	6,366	7,051	3,083
1909–10 . . .	14,121	22,544	4,261
1910–11 . . .	13,559	31,963	10,659
1911–12 . . .	6,072	16,498	9,154
1912–13 . . .	7,280	—	11,004

The total annual production of rubber in the three countries since the year 1905–6 has been as follows:

Year.	Tons.	Year.	Tons.
1905–6 . .	91	1909–10 . .	138½
1906–7 . .	106	1910–11 . .	158
1907–8 . .	75	1911–12 . .	102
1908–9 . .	64½		

The following account gives a brief summary of the rubber industry in each of the Protectorates:

Uganda

Rubber was first exported from Uganda in the year 1902–3, and up to the year 1908–9 the exports showed considerable variation, the minimum production being 34,530 lb. in 1907–8 and the maximum 73,191 lb. in 1906–7. During the next two years there was a large increase in the exports, which reached 105,909 lb. in 1909–10 and 101,352 lb. in 1910–11, this rise being due to the greatly increased production of rubber from the wild Funtumia trees. In 1911–12, however, the exports fell to only 45,923 lb.

The rubber-yielding plants indigenous to Uganda are *Funtumia elastica*, Stapf, and the vines *Landolphia Dawei*, Stapf, *Landolphia ugandensis*, Stapf, and *Clitandra orientalis*, K. Schum. *Landolphia ugandensis* is, however, not of much importance as a source of rubber in the Protectorate. Other species of Landolphia, such as *L. subturbinata*, Stapf, and *L. florida*, Benth., which do not yield rubber also occur.

Funtumia elastica was formerly thought to be restricted to western tropical Africa, but in 1903 Mr. M. T. Dawe, of the Uganda Forestry Department, discovered it in the Mabira Forest near the Victoria Nyanza, and since that date it has been found to occur freely in the other large forests of the Protectorate. *Funtumia elastica* is at present the most important source of Uganda rubber, and efforts have been made to preserve the wild trees so far as possible by leasing the rights of exploiting the forests to European companies. The Funtumia rubber

exported is obtained entirely from the forest trees, and is of very good quality, being prepared in the form of sheet or crêpe by machinery.

The rubber-yielding vines, *Landolphia Dawei*, Stapf, and *Clitandra orientalis*, K. Schum., grow principally on the outskirts of the forests or in those portions through which streams run. *Landolphia Dawei*, which is known locally as "Nansali," grows much more rapidly than most of the other rubber vines and attains a very great size. It furnishes a large yield of rubber which is of excellent quality. The other vine, *Clitandra orientalis*, is known as "Kapa." Its rubber is of very good quality, but it does not give such a large yield as *L. Dawei*.

The rubber is collected from these two species of vine by the natives, who make incisions a few inches apart on every available portion of the stem. The latex is coagulated by boiling, or by immersing the vessel containing it in boiling water, or by adding a coagulant. The latex of *C. orientalis* ("Kapa") is readily coagulated on heating, but that of *L. Dawei* ("Nansali") is not always coagulable by this method, and then salt or preferably acetic acid is added. The freshly coagulated rubber is usually pressed out into biscuits or sheets.

Experiments have also been conducted in Uganda with the principal exotic rubber trees in order to determine their suitability for cultivation in the Protectorate, and the results obtained with the Para and Ceara trees have been very promising. The Castilloa tree has been found to grow well in the country, but it is not suitable for general cultivation as it is subject to the attack of a borer (*Inesida leprosa*, Fab.) which does great damage to the trees.

Practically the whole of the rubber exported from Uganda up to the present has been derived from wild Funtumia trees or from the vines, but planting was commenced in 1908, and it was estimated that in 1912 there were 3,860 acres of cultivated rubber trees in the Protectorate. Of this total there were 3,000 acres under Para, 750 acres under Ceara, and about 100 acres under Funtumia and Castilloa.

East Africa Protectorate

The exports of rubber from the East Africa Protectorate showed a gradual decline from 182,863 lb. in 1904–5 to 81,424 lb. in 1908-9. During the next two years, however, there was a very large increase in the production, the exports amounting to 177,184 lb. in 1909–10 and to 193,312 lb. in 1910–11, the figures for the latter year representing the maximum export of rubber from the Protectorate in any one year since the commencement of the industry. In 1911–12, however, the exports declined to 135,184 lb.

The indigenous rubber plants of the Protectorate include (1) species of Landolphia vines, (2) *Mascarenhasia elastica*, K. Schum., the Mgoa rubber tree, and (3) *Funtumia elastica*, the West African rubber tree which has been recently discovered in the country bordering on the Victoria Nyanza.

The bulk of the wild rubber exported from the Protectorate has been hitherto obtained from the Landolphia vines. Of these the principal species is *L. Kirkii*, Dyer, which is abundant in the Coast Belt, whilst *L. watsoniana*, Vogtherr, and *L. ugandensis*, Stapf, are found on the Nandi plateau in the Nyanza Province at an elevation of 6,000 ft. *Landolphia kilimandjarica*, Stapf, is the source of the Laitokitok rubber obtained at a height of about 3,000 ft. on the northern slope of Mt. Kilimanjaro, and another rubber-yielding Landolphia vine has been recently discovered on the south-eastern slopes of Mt. Kenia. The principal rubber-yielding areas are the coast strip and the districts of Nandi and Lumbwa near the Victoria Nyanza. Only the coast areas have been systematically worked.

In tapping *Landolphia Kirkii* the natives cut off small slices of the bark and smear the wounds with salt water in order to accelerate the coagulation of the latex. The rubber obtained is wound into balls.

In 1906 the tree *Mascarenhasia elastica* was found to occur in the forests on the Shimba Hills, although it is not very abundant. Experiments are, however, being made in order to determine the yield of rubber which it will furnish, and its suitability for planting purposes. The rubber is usually obtained by making incisions in

the bark and allowing the latex to coagulate spontaneously on the stem.

At present there is little information available regarding the occurrence of *Funtumia elastica* in the East Africa Protectorate beyond the statement that the trees occur in considerable numbers in the forests of the Victoria Nyanza basin at altitudes of 5,000 to 6,000 ft.

Experiments have been made in the East Africa Protectorate with Para, Ceara, Funtumia, and Castilloa rubber trees. Except in a few favoured situations the climate, even in the Coast and Lake regions, is not suitable for the Para tree. The Ceara tree has, however, done very well, and large plantations of this species have been already formed.

Nyasaland

The exports of rubber from Nyasaland amounted to 118,239 lb. in 1899–1900 and to 86,404 lb. in 1900–1, but in the following year they fell to 14,393 lb. and the maximum production during the period 1901–2 to 1908–9 was 17,664 lb. In 1909–10 the exports rose to 27,144 lb., and during the next three years the figures were: 59,472 lb. in 1910–11, 47,709 lb. in 1911–12, and 61,112 lb. in 1912–13. It was stated that the large increase in 1910–11 was due principally to the more vigorous exploitation of the indigenous rubber vines, and in a lesser degree to an increase in the amount of plantation rubber produced.

The indigenous rubber-yielding plants of Nyasaland are vines or shrubs belonging to the genus Landolphia. The principal vine is *L. Kirkii*, Dyer, but *L. Droogmansiana*, De Wild., and other species also occur. Large numbers of these vines have been destroyed by the natives in collecting the rubber, but measures have been adopted for preserving the existing vines as far as possible. The bulk of the wild rubber exported is collected by the natives from vines in the West Nyasa district.

Two of the bushy forms of Landolphia, *L. parvifolia*, K. Schum., and *L. Thollonii*, Dewèvre, which furnish the so-called root-rubber, are also found in the West Nyasa district, and machines have recently been introduced for the extraction of the rubber from the underground stems of these plants.

Considerable attention has been devoted in Nyasaland to the cultivation of exotic rubber-yielding trees. It has been found that the climate of the Shiré Highlands is not suitable for the growth of the Para tree, and the only part of the Protectorate where this tree will thrive is the West Nyasa district. An area of 762 acres has been planted with Para in this district, but the trees are not yet ready for tapping.

The Ceara tree, on the other hand, has been found to grow well in many parts of Nyasaland and has been planted on a fairly large scale. In March 1913 there were 7,659 acres planted with this tree. The rubber obtained from the trees is of good quality and consignments have been sold at very satisfactory prices in London.

Zanzibar and Pemba

The island of Pemba possesses two indigenous rubber-yielding plants, viz., the vine *Landolphia Kirkii*, Dyer, and the tree *Mascarenhasia elastica*, K. Schum.

The Landolphia vine is very restricted in its distribution and only occurs in a small forest 3 or 4 miles in length with a mean width of 1 mile. The yield of rubber from the vines during 1909 and 1910 was about 1½ tons per annum.

Mascarenhasia elastica is reported to be fairly widely distributed in Pemba, but has not yet been found in Zanzibar island. It furnishes a small yield of rubber of good quality.

The Ceara tree has been introduced into both Zanzibar and Pemba and found to grow well. Considerable numbers of the trees have been planted by the Government and the natives, and tapping has already commenced.

Experiments are also being conducted with Para and Castilloa trees.

Transvaal

The rubber-yielding plants indigenous to the Transvaal consist of Landolphia vines, the principal of which is *Landolphia Kirkii*, Dyer. These vines occur in the Zoutpansberg and Lydenburg districts, situated in the north-eastern and eastern part of the Province, but they have not yet been exploited on a commercial scale.

Species of Euphorbia and Conopharyngia, which furnish resinous products, also occur in the Transvaal.

NATAL

The rubber vine *Landolphia Kirkii*, Dyer, known locally as "Ibungu," is indigenous in the forests of Tongaland in the northern portion of Natal, and is the source of the rubber produced in the Colony. The amount obtained is, however, only small at present. A species of Ficus (*Ficus utilis*, Sim) which yields a rubber-like material also occurs in the same district.

Recently quantities of the resinous product prepared from the latex of *Euphorbia Tirucalli*, L., have been exported to Europe, where the material is being utilised for certain technical purposes.

RHODESIA

The indigenous rubber-yielding plants of Rhodesia include species of Landolphia, Clitandra, and Carpodinus, which occur principally in Northern Rhodesia. The most important vine is *Landolphia Kirkii*, Dyer, but several shrubby plants which furnish rubber also occur, including *Landolphia parvifolia*, K. Schum., *Clitandra henriquesiana*, K. Schum., and *Carpodinus gracilis*, Stapf. The existence of a number of other native rubber-yielding plants has been recorded, but the botanical identity of these has not been definitely determined.

A number of exotic rubber trees have been tried experimentally in Rhodesia, and up to the present time the Ceara tree (*Manihot Glaziovii*) has given the best results.

CHAPTER III

THE PRINCIPAL RUBBER-YIELDING PLANTS

Geographical Distribution.—The rubber-yielding plants are practically restricted to the tropics, and their extreme geographical limits may be placed at about 28° north and south of the equator. They are most widely distributed in Central and South America and in tropical Africa, as the portion of Asia lying within the abovementioned limits is only small.

In America the area in which rubber plants are indigenous comprises Mexico, the States of Central America, some of the West Indian islands, Colombia, Venezuela, the Guianas, Ecuador, Peru, Bolivia, and Brazil.

Rubber plants are also found over practically the whole of Central Africa. They extend from Senegambia through West Africa, across the French Congo into the Bahr-el-Ghazal Province of the Anglo-Egyptian Sudan, and thence into Abyssinia. South of this line they are found right across the continent and also in Madagascar, the southern limit running from Portuguese West Africa through Rhodesia and the northern part of the Transvaal to Zululand on the east coast.

In Asia the occurrence of wild rubber plants is limited to India, Indo-China, the Malay Peninsula and the neighbouring islands. Rubber plants are also indigenous in New Guinea, Fiji, and other islands of the Pacific.

Botanical Source.—The principal rubber-yielding plants belong to one of the three natural orders Euphorbiaceae, Urticaceae, and Apocynaceae. A few of lesser importance belong to the natural order Asclepiadaceae, and the Guayule rubber plant of Mexico (*Parthenium argentatum*) is noteworthy in belonging to the order Compositae.

Plants belonging to these natural orders are quite

common outside the tropics, and some of the temperate species produce latex, which, however, does not yield rubber. The production of rubber-yielding latex is therefore restricted to the tropical species, but it must not be assumed that all tropical plants containing latex will furnish rubber. As a matter of fact only comparatively few of the laticiferous plants which occur in the tropics yield rubber of good quality, and in dealing with a laticiferous plant, the identity of which is not known, it is necessary to coagulate a quantity of the latex in order to determine the nature of the product before deciding that it is a rubber-yielding species. Many examples might be given of closely allied plants, such as *Funtumia elastica* and *Funtumia africana*, which each contain latex and are found growing in the same situations, but whereas the former furnishes rubber of excellent quality, the latter only gives a sticky resinous product of no commercial value. It is therefore necessary to discriminate carefully in many cases between closely related species of the same genus, some of which yield good rubber whilst the others furnish a worthless product.

The rubber-yielding plants include trees, climbers or vines, shrubs and herbs. In America the principal sources of rubber are trees belonging to the genera Hevea, Manihot, Castilloa, Sapium, Hancornia, and Micrandra, the rubber vines being represented by two species of the genus Forsteronia and the shrubs by the Guayule rubber plant of Mexico. In Africa, on the other hand, the majority of the indigenous rubber plants are vines or shrubs belonging chiefly to the genera Landolphia, Clitandra, Carpodinus, and Cryptostegia, and the rubber trees are restricted to *Funtumia elastica* and a few species of Mascarenhasia, Ficus, and Euphorbia; herbaceous rubber plants are also represented in Africa by the species of Raphionacme (principally *R. utilis*, Brown and Stapf) which contain rubber in their tuberous roots. Similarly rubber vines belonging to the genera Urceola, Willughbeia, Parameria, Ecdysanthera, Chonemorpha, Rhynchodia, Cryptostegia, etc., are abundant in Asia, and the principal rubber trees are *Ficus elastica*, *Dyera costulata*, and *Bleekrodea tonkinensis*.

The following account enumerates the principal rubber-

yielding plants of the world grouped according to their natural orders:

I. *EUPHORBIACEAE*

1. *Hevea brasiliensis*, Müll. Arg., the Para rubber tree. This is the most important rubber-yielding plant, since it furnishes the greater part of the world's supply of rubber, either from wild trees in the Amazon valley or from cultivated trees in Asia. The rubber derived from this tree is also of the highest quality, and the "fine hard Para" from South America forms the market standard of price.

Hevea brasiliensis is a large forest tree which occurs wild throughout the entire valley of the Amazon and its tributaries to the south of the main stream. It has been found to grow well in suitable situations throughout the tropics, and is now being cultivated extensively in Ceylon, the Malay Peninsula, India, Sumatra, Java, and other countries.

A number of other species of Hevea also occur in South America, some of which are known to yield good rubber, but they are of less importance than *Hevea brasiliensis*.

A description of the Para rubber tree and its allies is given in chap. ix. p. 101.

2. *Manihot Glaziovii*, Müll. Arg., the Ceara rubber tree. This tree is a native of the north-eastern portion of Brazil, especially in the province of Ceara, where the climate is much drier than in the Amazon valley. It furnishes the rubber known as Maniçoba in Brazil.

The Ceara tree has been introduced into almost all tropical countries, and it is now being cultivated on a large scale in East Africa. If carefully prepared, the rubber is of excellent quality, and plantation Ceara rubber is practically equal in value to plantation Para.

Three other species of Manihot which also yield rubber have been discovered within the last few years in eastern Brazil and have been named *Manihot dichotoma*, *M. heptaphylla*, and *M. piauhyensis*. It is stated that in Brazil these species are superior to *Manihot Glaziovii* as sources of rubber, and they are being cultivated experimentally in many countries at the present time for comparison with the Ceara tree.

The rubber-yielding species of Manihot are described in chap. x. p. 137.

3. *Sapium* spp.

A number of trees belonging to the genus Sapium occur throughout the northern part of South America, being found in Colombia, Venezuela, British Guiana, Ecuador, Peru, and the Amazon valley. Rubber of good quality is known to be furnished by some of these trees, but the botanical identity of the rubber-yielding species is not in all cases fully established. It appears certain that the "caucho blanco" rubber from Colombia is derived from a species of Sapium which Jumelle believes to be *Sapium utile*, Preuss.

In Brazil only one species of Sapium, *S. Taburu*, Ule, is known to yield good rubber. This tree is very common in certain districts on the alluvial lands along the main river and its tributaries. The latex is generally mixed with that of *Hevea brasiliensis*, but in those districts where the latter species does not occur, the rubber of *S. Taburu* is prepared by allowing the latex to coagulate on the tree and then collecting it in ball form.

Several species of Sapium occur in British Guiana, and two of these, *Sapium Jenmani*, Hemsl., and *Sapium cladogyne*, Hutchinson, yield rubber of good quality. Authentic specimens of the rubber obtained from forest trees of *Sapium Jenmani* were found on examination at the Imperial Institute to be very little inferior in composition and value to the best Para rubber. The following analysis of a sample specially prepared in biscuit form by Mr. C. Wilgress Anderson, of the Forestry Department, may be quoted :

	Per cent.
Moisture	0·7
Caoutchouc	93·7
Resin	1·8
Protein	3·2
Ash	0·6

This sample was valued at 4*s*. 3*d*. per lb. in London with fine hard Para at 4*s*. 3½*d*. per lb., and plantation Para biscuits at 4*s*. 4*d*. to 4*s*. 11*d*. per lb.

Sapium Jenmani has been planted on a small scale in

British Guiana and experiments have been made to determine the yield of rubber from forest trees. Interesting results have been obtained from tapping experiments conducted during a period of two years on old trees growing on the river bank at the Bonasika Reserve. The average yield of rubber during this period was 18·33 oz. per tree, but it was found that whereas the rubber obtained from the first tappings was of excellent quality, the product from the later tappings was soft and tacky. This point is of considerable importance as it affects the value of the tree for planting purposes. The results so far obtained from young plantation trees have been disappointing, and it seems doubtful whether *Sapium Jenmani* can be recommended for cultivation in British Guiana.

Further details regarding the rubber of *S. Jenmani* will be found in the Imperial Institute *Selected Reports on Rubber and Gutta Percha*, pp. 280–4.*

4. *Micrandra siphonioides*, Benth.

The genus Micrandra is very closely related to Hevea, but is distinguished from it by its undivided leaves and its smaller capsules and seeds. The best known of the Brazilian species is *Micrandra siphonioides*, a large tree growing in the Rio Negro area, which according to Ule yields good rubber. The tree is, however, not exploited to any extent by the natives, as its latex cannot be mixed with that of the species of Hevea growing in the same district. It is stated, however, that rubber is prepared from species of Micrandra on the Putumayo and Ucayali rivers.

5. *Euphorbia* spp.

Most of the tropical species of Euphorbia yield latex freely, but the product which the latter furnishes on coagulation is usually of resinous character and becomes hard and brittle on keeping.

The most important species of Euphorbia as sources of rubber or rubber-like material are *Euphorbia Intisy*, Dr. d. Cast., which furnishes the Intisy rubber of southern Madagascar; *Euphorbia rhipsaloides*, Welw., a native of Angola, from which the resinous product known as "almeidina" or "potato gum" is derived; *Euphorbia Tirucalli*, L., which has been recently exploited in Natal;

* *Colonial Reports—Miscellaneous*, No. 82. Wyman & Sons, Ltd.

and *Euphorbia fulva*, Stapf, the Palo Amarillo tree of Mexico.

A large number of specimens of the products obtained in South Africa from the latex of species of Euphorbia have been examined at the Imperial Institute, and several typical analyses are given in *Selected Reports on Rubber and Gutta Percha*, pp. 416–21. The results show that the resin in the dry material may range from 56·1 to 92·8 per cent., and the caoutchouc, which is usually of inferior quality, from 6·7 to 32·1 per cent.

A specimen of the product stated to be derived from the latex of *Euphorbia Tirucalli* in Natal was found on analysis at the Imperial Institute to have the following composition :

	Material as received. Per cent.	Composition of dry material. Per cent.
Moisture	32·4	—
Caoutchouc	9·7	14·3
Resin	51·2	75·8
Protein	0·9	1·3
Insoluble matter	5·8	8·6
Ash	2·5	3·7

This product from *Euphorbia Tirucalli* is utilised, like "almeidina," for mixing purposes in rubber manufacture.

II. *URTICACEAE*

6. *Castilloa elastica*, Cerv., the Central American rubber tree.

The habitat of this tree includes southern Mexico, Central America, some of the West Indian islands, Colombia, and the western slopes of the Andes in Ecuador and Peru. Large Castilloa plantations have been established in Mexico, and the cultivation of the trees has also been undertaken on a smaller scale in some of the States of Central and South America, and in the West Indies, particularly in Trinidad and Tobago. The tree has also been introduced into Africa and Asia, but it has not given very good results when cultivated outside Central and South America.

The well-prepared rubber, as obtained on the plantations in Mexico and the West Indies, is of very good quality.

A further description of this tree is given in chap. xiii. p. 212.

Another rubber-yielding species of Castilloa, which has been named *Castilloa Ulei*, Warb., occurs in the Upper Amazon valley and furnishes the Caucho rubber obtained from that region.

7. *Ficus* spp. A number of rubber-yielding species of Ficus occur in Asia and Africa, and of these the following may be mentioned :

(*a*) *Ficus elastica*, Roxb., the Assam rubber tree. This tree, the well-known indiarubber plant grown for ornamental purposes in this country, is a native of Assam, Burma, the Malay Peninsula, Sumatra, and Java. In its natural habitat it is a large forest tree with buttress roots, and the branches give rise to numerous adventitious roots which grow to the ground and form subsidiary stems. It has been planted in Assam, the Malay Peninsula, Sumatra, and Java, but its cultivation has now been largely abandoned in Malaya in favour of the Para tree.

The rubber of *Ficus elastica* is somewhat variable in composition. In some situations the tree furnishes rubber of excellent quality, whereas in others it yields a product containing a considerable percentage of resin.

A fuller description of this tree will be found in chap. xiv. p. 227.

(*b*) *Ficus Vogelii*, Miq. This tree is a native of West Africa, its habitat extending from the Gambia to the mouth of the Congo. The rubber is of inferior quality on account of the large percentage of resin present, but it is exported from Northern Nigeria under the name of "balata" and is utilised for certain technical purposes (see chap. xiv. p. 234).

(*c*) Several African species of Ficus, including *Ficus platyphylla*, Del., *Ficus trachyphylla*, Fenzl., and *Ficus bibracteata*, Warb., yield a hard, resinous product, somewhat resembling gutta percha in properties, which is exported from Northern Nigeria (see chap. xiv. p. 236).

(*d*) A number of other rubber-yielding species of Ficus are known, such as *Ficus Schlechteri*, Warb., and *Ficus Rigo*, Bailey, both of which occur in New Guinea.

The Imperial Institute *Selected Reports on Rubber and Gutta Percha* contain (pp. 348–51) analyses of a number of products derived from other species of Ficus, such as *Ficus comosa*, *F. indica*, and *F. rubra*, which are, however, of no commercial interest.

8. *Bleekrodea tonkinensis*, Dub. and Eberh. This tree occurs in Tonkin, and is stated to yield rubber of good quality which is collected by the natives. The base of the tree is tapped and the latex is coagulated by boiling.

III. *ASCLEPIADACEAE*

9. *Cryptostegia* spp.

(*a*) *Cryptostegia grandiflora*, R. Br. This species of Cryptostegia occurs in Madagascar, Reunion, and India, and has been introduced into Mexico and the Bahamas where it now grows freely. It is a climbing plant or vine and yields rubber of good quality, which, however, is very difficult to obtain by tapping.

Several samples of the rubber from India and the Bahamas have been examined at the Imperial Institute, and the following analyses may be given:

	Ball rubber from Gwalior. Per cent.	Biscuit rubber from Bahamas. Per cent. (*a*)	(*b*)
Caoutchouc . . .	74·2	89·2	86·8
Resin	9·7	8·2	9·1
Protein	11·5	1·9	3·8
Ash	4·6	0·7	0·3

It will be seen from these figures that the rubber is of good quality if carefully prepared. Analyses of other specimens of the rubber from India are given in Imperial Institute *Selected Reports on Rubber and Gutta Percha*, pp. 400–2.

(*b*) *Cryptostegia madagascariensis*, Boj. This plant, which is stated to grow sometimes as a vine and sometimes as a shrub, is the source of the "lombiro" rubber of Madagascar. The yield of rubber from the plant is small and the product is of inferior quality, being usually soft and deficient in elasticity. It is stated that the rubber is employed for some special purpose in Germany for which it commands an increased price.

10. *Raphionacme utilis*, Brown and Stapf.

This recently discovered rubber plant is a native of

Portuguese West Africa, where it is known by various native names, such as "bitinga," "ecanda," and "marianga." It is of considerable interest owing to the fact that the latex is contained in the tuberous roots.

Specimens of the roots and of the rubber obtained from them have been examined at the Imperial Institute. The average yield of rubber from the dry roots was found to be 10·5 per cent., but the roots as received contained a very large amount of moisture and only from 1·0 to 1·5 per cent. of rubber.

The rubber is of very fair quality, as will be seen from the following analysis of a sample prepared by the natives in Portuguese West Africa:

	Per cent.
Moisture	1·0
Caoutchouc	76·8
Resin	9·0
Protein	0·6
Insoluble matter	12·6
Ash	7·11

The chief defect of the sample is the large amount of insoluble impurity present. For further information regarding this rubber see Imperial Institute *Selected Reports on Rubber and Gutta Percha*, pp. 409–11.

Attempts have been made to cultivate this plant, but the results so far obtained have not been very encouraging.

11. *Periploca nigrescens*, Afzel.

12. *Dregea rubicunda*, K. Schum.

These two vines are found in the Belgian Congo. They are stated to yield rubber, but they are not of much importance as sources of the product.

IV. *APOCYNACEAE*

13. *Funtumia elastica*, Stapf (*Kickxia elastica*, Preuss), the African rubber tree or Lagos silk rubber tree.

This tree, which owes its name of "silk rubber tree" to the fact that its seeds have an attachment of silky hairs, is the most important rubber-yielding plant indigenous to Africa. It is widely distributed in northern tropical Africa, extending across the continent from Sierra Leone to the East Africa Protectorate and southwards into the Belgian Congo.

Funtumia elastica is very abundant in the forests of the Gold Coast and Southern Nigeria, and large numbers of the trees have been planted in both these countries; it also occurs freely in Uganda. The well-prepared rubber is of very good quality and realises a high price, but much of the product obtained by the natives is of low value owing to defective methods of preparation.

This tree is dealt with fully in chap. xi. p. 160.

14. *Mascarenhasia* spp.

Rubber is furnished by several small trees belonging to the genus Mascarenhasia which occur in East Africa and Madagascar.

Mascarenhasia elastica, K. Schum., which is found in the East Africa Protectorate, the island of Pemba, German East Africa, and Portuguese East Africa, yields a small amount of rubber which is usually obtained by making incisions in the stem and allowing the rubber to coagulate spontaneously in the cuts. The strips of rubber thus formed are then wound into balls. If carefully collected, the rubber is of satisfactory composition and good quality. The product is known as Mgoa or Goa rubber in the East Africa Protectorate and in German East Africa, and as N'harasika in Portuguese East Africa.

A number of specimens of the rubber of *Mascarenhasia elastica* from East Africa have been examined at the Imperial Institute (see *Selected Reports on Rubber and Gutta Percha*, pp. 404–8), and the following analyses may be quoted as showing the composition of the dry rubber:

		East Africa Protectorate.	Pemba.	Portuguese East Africa.			
				(1)	(2)	(3)	(4)
Caoutchouc	Per cent.	76·6	85·2	92·1	82·6	81·1	80·1
Resin	,,	6·8	9·0	4·6	7·1	7·5	8·1
Protein	,,	3·9	3·7	2·4	3·8	3·8	3·9
Insoluble matter	,,	12·7	2·1	0·9	6·5	7·6	7·9
Ash	,,	2·54	1·29	2·0	1·8	1·9	1·9

Four of the samples analysed contained rather large amounts of insoluble impurity, but specimen (1) from Portuguese East Africa is of very good quality, the quantity of caoutchouc reaching 92 per cent.

No definite information is available as to the average

yield of rubber which the trees will furnish, but experiments are in progress in East Africa with the object of determining this point and also the suitability of the trees for cultivation.

Several other rubber-yielding species of Mascarenhasia occur in Madagascar, viz. *M. lisianthiflora*, A.DC., *M. anceps*, Boiv., and *M. longifolia*, Jum., which collectively furnish the rubber known as Gidroa.

15. *Hancornia speciosa*, Müll. Arg., the Mangabeira rubber tree.

This tree is widely distributed throughout Brazil, but the rubber is chiefly collected in the States of Bahia and Pernambuco, and also in Minas Geraes, Goyaz, and São Paulo. It is a small tree which bears an edible fruit about the size of a plum. The latex is usually coagulated by the addition of a solution of alum or common salt, and the rubber is frequently impure and of inferior quality.

16. The African rubber vines belonging to the natural order Apocynaceae.

The Apocynaceous rubber vines occurring in Africa belong almost entirely to the three genera Landolphia, Clitandra, and Carpodinus. These plants are usually found in the forests, where they occur as strong climbers or vines often of large size ; they attach themselves to the trees on which they grow by means of strong hooked tendrils. A number of the species are also met with on open country, where, in the absence of any trees to serve as supports, they develop a bushy habit. In other cases the plants only occur as dwarf shrubs or undershrubs with partly herbaceous branches, and the rubber is obtained from their underground stems (rhizomes).

Rubber vines are widely distributed throughout Central Africa. Their northern limit runs from Senegambia to Abyssinia and their southern limit from Portuguese West Africa to Zululand. Within this area they are found right across the continent and a number of species also occur in Madagascar.

It may, perhaps, be mentioned that there are in Africa many Apocynaceous vines containing latex, which, however, does not yield a marketable rubber.

The African rubber vines are dealt with in chap. xii. p. 186, but a list of the principal species with their geographical distribution may be given here.

(*a*) *Landolphia* spp.

Landolphia Heudelotii, A.DC. West Africa from Senegambia to Sierra Leone, and the southern portion of the French Sudan.

Landolphia owariensis, Beauv. West Africa from Sierra Leone to Angola, the French and Belgian Congo, and the Bahr-el-Ghazal Province of the Anglo-Egyptian Sudan.

Landolphia Gentilii, De Wild. Belgian Congo.

Landolphia Droogmansiana, De Wild. Belgian Congo and Nyasaland.

L. Gentilii and *L. Droogmansiana* are very closely related to *L. owariensis*.

Landolphia Klainei, Pierre. Cameroons, Gaboon, French and Belgian Congo.

Landolphia Kirkii, Dyer. East Africa from Abyssinia to Zululand.

Landolphia dondeensis, Busse. German East Africa. This vine is closely related to *L. Kirkii*.

Landolphia Stolzii, Busse. German East Africa.

Landolphia Dawei, Stapf. Uganda and probably the Belgian Congo.

Landolphia watsoniana, Vogtherr. East Africa Protectorate and German East Africa.

Landolphia ugandensis, Stapf. Uganda and East Africa Protectorate.

Landolphia kilimandjarica, Stapf. On Mt. Kilimanjaro in East Africa.

Landolphia madagascariensis, K. Schum. Madagascar.

Landolphia Perrieri, Jum. Madagascar.

Landolphia sphaerocarpa, Jum. Madagascar.

Landolphia Thollonii, Dew. French and Belgian Congo, Angola, and Nyasaland.

Landolphia parvifolia, K. Schum. Angola, Rhodesia, and Nyasaland.

Landolphia chylorrhiza, Stapf. Angola.

(*b*) *Clitandra* spp.

Clitandra orientalis, K. Schum. Uganda and German East Africa.

Clitandra Arnoldiana, De Wild. (closely related to *C. orientalis*). Belgian Congo.

Clitandra elastica, Chev. (also related to *C. orientalis*).

West Africa from Ivory Coast to Southern Nigeria.

Clitandra sp., cf. *C. laxiflora*, Hallier f. Sierra Leone.

Clitandra henriquesiana, K. Schum. Angola and Northern Rhodesia.

(c) *Carpodinus* spp.

Carpodinus hirsuta, Hua. West Africa from Senegambia to Nigeria.

Carpodinus leucantha, K. Schum. Angola.

Carpodinus gracilis, Stapf. Belgian Congo and Angola.

17. The Asiatic rubber vines belonging to the natural order Apocynaceae.

A large number of Apocynaceous rubber vines occur in the forests of India, Indo-China, the Malay Peninsula, and the neighbouring islands. The principal species are given in the following list:

Urceola elastica, Roxb.
Urceola esculenta, Benth.
Willughbeia firma, Blume.
Chonemorpha macrophylla, G. Don.
Rhynchodia Wallichii, Hook. f.
Ecdysanthera micrantha, A.DC.
Parameria glandulifera, Benth.
Hymenolophus Romburghii, Boerl.
Michrechites napeensis, Quint.
Xylinabaria Reynaudi, Jum.

Many of these vines yield rubber of very good quality, but the value of the product is often reduced by the native methods of preparation. The following analyses, made at the Imperial Institute, will indicate the composition of the dry rubber from certain of the vines:

	Caoutchouc.	Resin.	Protein.	Insoluble matter.	Ash.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Urceola esculenta . .	83·9	10·2	—	5·9	1·2
,, ,, . .	81·8	7·5	—	10·7	1·8
,, ,, . .	77·7	18·5	—	3·8	1·0
Chonemorpha macrophylla	60·0	37·6	—	2·4	1·0
Rhynchodia Wallichii .	89·0	6·7	—	4·3	0·5
Ecdysanthera micrantha .	84·1	11·5	—	4·4	1·3
Parameria glandulifera .	91·8	6·3	1·4	—	0·5
,, ,,	91·6	5·8	1·9	—	0·7

For further particulars regarding the above rubbers reference should be made to Imperial Institute *Selected Reports on Rubber and Gutta Percha*, pp. 392–400.

18. The American rubber vines belonging to the natural order Apocynaceae.

The Apocynaceous rubber vines are represented in America by the genus Forsteronia, of which there are two species, *F. floribunda*, G. Don, and *F. gracilis*, Müll. Arg.

F. floribunda occurs freely in the limestone districts of Jamaica, and, as will be seen from the following analysis made at the Imperial Institute, it furnishes rubber of good quality :

	Per cent.
Caoutchouc	88·8
Resin	7·1
Protein	1·6
Insoluble matter . . .	2·5
Ash	1·4

The rubber is, however, difficult to obtain from the vines by tapping.

19. A number of rubber-yielding vines occur in some of the Pacific islands. In Fiji rubber is obtained from several species of Alstonia, the principal of which is stated to be *A. plumosa*, Labill., and in British New Guinea rubber vines also occur and are tapped by the natives.

20. *Dyera costulata*, Hook. f., the Jelutong tree.

The inferior rubber-like material known as Jelutong or Pontianac is derived from several species of Dyera, the principal of which is *Dyera costulata*. The trees occur in the Malay Peninsula, Sumatra, and Borneo.

Dyera costulata is a very large tree, the trunk of which may attain a diameter of 4 to 6 ft. It yields a large quantity of latex which the natives coagulate by stirring with a little kerosene, after adding a small quantity of powdered gypsum. The product is usually prepared in the form of large balls or cheese-shaped masses. It is white and granular, and when freshly prepared contains as much as 60 per cent. of moisture. The dry material contains about 15 per cent. of caoutchouc, the remainder being resin.

Large quantities of Jelutong are exported from Singapore to Europe and America for use in rubber manufacture.

V. *COMPOSITAE*

21. *Parthenium argentatum*, A. Gray, the Guayule rubber plant.

This plant is of interest as it is the only member of the natural order Compositae which furnishes rubber in sufficient quantity to be of commercial importance. It is a small shrub which attains a height of about 3 ft. and has a much branched stem bearing small silver-grey leaves and yellow flower heads. The plant formerly occurred wild over a large portion of the "bush prairies" in northern Mexico, but owing to the extent to which it has been exploited during recent years the supply is rapidly diminishing.

The latex is contained in isolated cells which are principally situated in the bark, but also occur in the pith and the medullary rays. The rubber cannot be obtained by making incisions in the stem as the latex does not exude, and it must, therefore, be extracted by a mechanical process or by treatment with solvents. The crude rubber contains a rather large proportion of resin (20 to 30 per cent.), but a superior product is obtained by removing the greater part of the resin by treatment with a suitable solvent. The yield of crude rubber is stated to be from 8 to 12 per cent. according to the amount of moisture present in the plants treated, and the yield of the purified rubber from 7 to 8 per cent.

CHAPTER IV

LATEX

Laticiferous Tissues of Plants.—The latex of plants is contained in a system of special tubes, vessels, or cells which are usually present in every part of the plant, in the root, stem, branches, leaves, and fruit. Three types of laticiferous tissue occur in plants, viz. non-articulated tubes, articulated vessels, and single cells (sacs), and examples of each of these forms are found amongst the rubber-yielding plants.

The non-articulated tubes are developed from special laticiferous cells present in the embryo which grow and branch in the tissues as the plant increases in size. These cells may therefore attain an enormous length and they are not divided in any way. Such elongated laticiferous tubes are present in the seedlings of *Castilloa elastica*, *Funtumia elastica*, and other rubber-yielding plants.

The articulated vessels, on the other hand, are developed in the tissues from longitudinal rows of special cells. The transverse walls of these cells undergo absorption forming long, continuous tubes (vessels) which become filled with latex. The adjacent vessels frequently communicate with one another by lateral passages, and thus produce a complete network in the tissues. Articulated laticiferous vessels of this type are well seen in *Hevea brasiliensis*, the Para rubber tree, and in *Manihot Glaziovii*, the Ceara rubber tree.

A third type of laticiferous tissue consists of isolated cells which are known as sacs. These cells are frequently arranged in longitudinal rows, but they do not communicate with one another. This form is not common amongst rubber plants, but it occurs in the Guayule plant, *Parthenium argentatum*, A. Gray, belonging to the natural order Compositae, and it is also met with in the trees which

yield gutta percha, *Palaquium* spp. of the natural order Sapotaceae.

A full knowledge of the nature of the laticiferous tissue in the different rubber-yielding plants and of its distribution and the mode of its formation in the cortex of the tappable trees would probably be of great assistance in devising methods of tapping suited to the peculiarities of the various species, but at present the information available on this subject is somewhat limited. The principal investigations of the laticiferous tissues of rubber-yielding plants have been conducted with *Hevea brasiliensis* and *Manihot Glaziovii*, and have been largely confined to the seedlings of these plants.

Scott * first demonstrated in 1885 that the laticiferous tissue of *Hevea brasiliensis* seedlings consisted of articulated vessels formed from a number of separate cells. Working with seedlings up to thirty-six days old, he found that well-developed laticiferous vessels, containing abundant latex, were present in the cotyledons of the germinating seeds, and that these vessels were always produced on the phloem side of the bundles. The transverse walls of the original cells could be easily traced in different stages of absorption, and even at this early period numerous perforations of the lateral walls had occurred, thus establishing communication between adjacent vessels and producing a complete anastomosing system of laticiferous tubes. He further found that the cortex of the seedlings contained a similar network of laticiferous vessels which could be traced up to the youngest leaf at the apex of the stem but not into the apical cone.

Miss Calvert † subsequently found that a small number of laticiferous vessels also occur in the pith of Hevea seedlings, and that the vessels of the pith and cortex communicate with one another at the nodes.

Fitting ‡ has since confirmed the conclusions of Scott and Miss Calvert regarding the distribution of the laticiferous vessels in Hevea seedlings, and has also examined trees from one to three years old. In the latter he found a number of laticiferous vessels in the outer part of the pith and showed that these were mutually connected.

* *Journal of Linnean Society*, xxi. pp. 566–70.
† *Annals of Botany*, i. pp. 75–7.
‡ *Beihefte zum Tropenpflanzer*, 1909.

He also observed that in the green portions of the stem communications between the vessels of the pith and cortex occur at the nodes.

Arens has also noted the occurrence of laticiferous vessels in the pith of Hevea trees. In a six-year-old tree which was 24 in. in girth at 3 ft. from the ground, he found from 13 to 20 laticiferous vessels in the pith.

The cortex of mature Hevea trees contains numerous laticiferous vessels which run in a longitudinal direction, *i.e.* parallel to the axis of the plant, and form a complex network by reason of their lateral communications. It is these vessels which are of interest to the rubber planter, and a general account of their development and distribution will be given in the next chapter.

The nature of the laticiferous tissue in the seedlings of *Manihot Glaziovii*, the Ceara rubber tree, was also investigated by Scott * and afterwards by Miss Calvert and L. Boodle.† These workers found that this species resembles *Hevea brasiliensis* in having articulated laticiferous vessels which occur both in the cortex and the pith of seedlings. The vessels in the cortex are connected by numerous lateral passages, as in the case of Hevea.

Little information is available regarding the laticiferous tissue of other rubber-yielding plants. It has been stated already that the seedlings of *Funtumia elastica* and *Castilloa elastica* contain non-articulated laticiferous tubes formed by the growth of cells present in the embryo, but no observations appear to have been published as to the nature of the laticiferous tissue in the cortex of the mature trees.‡

Characters of Latex.—The latex is usually a white fluid, almost indistinguishable from milk in appearance; sometimes, however, it is cream or yellow in colour and occasionally pinkish or pale reddish-brown owing to the presence of colouring matter in the bark. Like milk, it is an emulsion, and consists essentially of a watery fluid containing various substances in solution and holding in suspension the minute globules of rubber substance. These globules, which correspond to the fat globules of

* *Quarterly Journal of Microscopical Science*, xxiv. pp. 194–204.

† *Annals of Botany*, i. pp. 55–62.

‡ For further information on this subject see, however, *L'Appareil laticifère des Caoutchoutiers*, by Dr. A. Meunier (Imprimerie Industrielle et Financière, 4, Rue de Berlaimont, Bruxelles).

milk, usually exhibit very rapid Brownian movement when a drop of the latex is examined with a microscope under a high power. The globules vary considerably in size in different latices, and even in the same latex the range is often great, so that it is not surprising that the measurements recorded by different observers show wide variations. According to Seeligmann, the globules of Para latex have a mean diameter of 0·0035 mm., whereas Henri found them to vary from 0·0005 to 0·002 mm. Petch has examined the latex from the stem of a twenty-three-year-old Para tree grown at Peradeniya in Ceylon, and according to his measurements the globules range from 0·0005 to 0·003 mm. in diameter, but he points out that many of them had a distinct tail; he further records that the latex from a green shoot of the same Para tree contained very minute granules, which were too small to measure with a magnification of 600 diameters, and a few globules about 0·001 mm. in diameter. Petch also examined the latex of a Castilloa tree growing in Ceylon and found the globules to range from 0·0015 to 0·003 mm. in diameter. He states that the largest Hevea globules are the same size as the largest Castilloa globules, but that the average size of the Castilloa globules is greater than that of the Hevea globules.

Fickendey found that the globules of *Hevea brasiliensis* latex varied from 0·0005 to 0·001 mm. in diameter, whilst those of *Ficus elastica* and *Castilloa elastica* ranged from 0·002 to 0·003 mm.

Jumelle has recorded the following measurements for the globules in the latex of certain vines: *Landolphia Perrieri*, 0·0022 mm. (mean); *Cryptostegia madagascariensis*, 0·0012 to 0·0023 mm.; and *Xylinabaria Reynaudi*, 0·002 to 0·0025 mm.; whilst Lecomte found the globules of *Landolphia owariensis* latex to be 0·001 mm. in diameter.

The specific gravity of latex is usually a little below that of water, and a large number of determinations have been recorded for different latices giving values ranging from 0·956 to 0·997. The latex of *Castilloa elastica* appears, however, to have a specific gravity slightly greater than that of water: Collens records values of 1·003 and 1·005 for two samples of the fresh latex in Trinidad; whilst Kaye gives 1·0135 for a sample in Mexico. Recently, too, Bamber in Ceylon found that a sample of

Para latex containing 32 per cent. of caoutchouc had a specific gravity of 1·018 at 60° F. Beadle and Stevens examined a large number of specimens of Para latex from eight-year-old trees, and their results show specific gravities ranging from 0·973 to 0·980 with a mean of 0·975; they also found specific gravities of 0·975, 0·974, and 0·975 for three specimens of Rambong latex (*Ficus elastica*). Spence gives the specific gravity of a specimen of *Funtumia elastica* latex containing only 20 per cent. of caoutchouc as 0·9989, and Fickendey records a value of 0·988 at 25° C. for the latex of this species. A sample of *Landolphia owariensis* latex examined at the Imperial Institute had a specific gravity of 0·956.

Composition of Latex.—The latex as it exudes from the stem is usually slightly acid, but it may be neutral, or even faintly alkaline.

In addition to the globules of rubber substance, latex always contains varying amounts of resin and protein, and the aqueous liquid holds in solution various salts (organic and inorganic), free organic acids, carbohydrates, and other substances. The following analyses of Para latex which have been recorded by Bamber and by Beadle and Stevens will indicate its general composition:

	Bamber.		Beadle and Stevens.	
	Per cent.	Per cent.	Per cent.†	Per cent.‡
Water	55·15	55·56	70·00	60·00
Caoutchouc	41·29	32·00	27·07	35·62
Resins	—	2·03	1·22	1·65
Protein	2·18	2·03	1·47	2·03
Ash	0·41	9·07*	0·24	0·70
Sugar	0·36	—	—	—

Beadle and Stevens have also recorded the following analyses of the latices of Rambong (*Ficus elastica*) and Castilloa trees grown in the Malay Peninsula:

	Rambong.	Castilloa.
	Per cent.	Per cent.
Water	59·5	62·7
Caoutchouc	37·3	31·2
Resin	2·4	5·0
Protein	0·4	0·2
Ash	0·4	0·9

* Mineral matter. † Four-year-old trees. ‡ Ten-year-old trees.

A sample of *Funtumia elastica* latex from West Africa was found by Spence to have the following composition :

	Per cent.
Water	76·20
Caoutchouc	19·85
Resins (soluble in acetone) . . .	2·00
Organic crystalloids (sugars, organic acids, and certain nitrogenous compounds)	1·39
Insoluble constituents (largely protein) .	0·36
Protein (calculated from nitrogen 0·438)	2·73
Mineral matter (ash)	0·266

Fickendey examined a sample of *Funtumia elastica* latex from the Cameroons and found it to have the following composition :

	Per cent.
Water	47·68
Ash	0·99
Lead acetate precipitate . .	1·98
Peptones	3·25
Rubber	40·72
Resin	4·46

The proportion of rubber present in latex varies considerably in different plants and also in the same plant at different seasons according to the consistence of the latex, which in its turn depends upon the supply of water. In the case of plants growing in districts which have a marked wet and dry season, the latex is usually thin and watery during the rainy period and then contains only a low percentage of rubber, whereas during the dry season it becomes very much thicker owing to the utilisation by the plant of the water of the latex, and the proportion of rubber is correspondingly increased. Further, the amount of rubber in latex is considerably affected by the manner and frequency of tapping. It has been found that if Para trees are regularly tapped at frequent intervals the percentage of rubber in the latex is diminished ; whereas if longer intervals are allowed between

the tappings, the effect is much less marked. Thus, for example, Bamber and Lock in Ceylon found that the amount of rubber in the latex of Para trees tapped every day or every second day rapidly fell from 50 per cent. to about 30 per cent.; if, however, an interval of four five, six, or seven days was allowed between the tappings, the proportion of rubber did not fall much below 40 per cent. Beadle and Stevens have recorded that in the Federated Malay States Para trees seven to eight years old which were lightly tapped every other day furnished latex containing an average of 37·5 per cent. of rubber, whereas the corresponding figure for similar trees which were more heavily tapped at the same intervals was only 27·5 per cent. In abnormal cases the latex of cultivated Para trees has been found to contain such a small percentage of rubber that it could not be coagulated by the usual methods, whilst, on the other hand, the latex of a thirty-year-old tree in Ceylon has furnished as much as 64 per cent. of dry rubber. It will be seen, therefore, that very considerable variations occur.

Christy determined the amount of dry rubber in a number of specimens of Funtumia latex obtained from forest trees in Uganda. In twenty-six trees the proportion of dry rubber in the latex ranged from 24·4 to 46·6 per cent., whilst two other trees were abnormal, the latex containing only 8·5 and 11 per cent. of dry rubber.

Three specimens of the latex of *Landolphia owariensis* examined at the Imperial Institute were found to contain respectively 44·1, 44·8, and 51·3 per cent. of dry rubber.

The most important constituents of latex other than the caoutchouc, so far as the preparation of rubber is concerned, are the resin and protein, since these substances are always included in the coagulated product. Some of the mineral matter of the latex is also invariably present in crude rubber and occasionally small amounts of the carbohydrates in addition.

Resin.—The proportion of resin present in latex is subject to very wide variation and the ratio of resin to caoutchouc largely determines the value of a latex as a source of commercial rubber. The following analyses, made at the Imperial Institute, will illustrate the variation which may occur in the composition of the product obtained from different latices:

	Para rubber.	Rubber of *Ficus Vogelii.*	Product of *Euphorbia* sp.
	Per cent.	Per cent.	Per cent.
Caoutchouc . .	96·5	52·3	6·7
Resin . . .	1·9	44·4	92·8
Protein . . .	1·4	2·3	0·3
Ash . . .	0·2	1·0	0·2

It will be seen from these figures that the Para tree will furnish rubber containing 96·5 per cent. of caoutchouc and only 1·9 per cent. of resin, whilst at the other end of the scale the products derived from the latex of certain species of Euphorbia may contain only 6·7 per cent. of caoutchouc and 92·8 per cent. of resin. Between these extremes every variation is possible, and the analysis of the specimen of *Ficus Vogelii* rubber quoted above illustrates a case in which caoutchouc and resin are in nearly equal proportions. The presence of a large amount of resin adversely affects the physical properties of the rubber, rendering it soft, weak, and inclined to be sticky, whilst the products in which resin predominates do not usually exhibit the characteristic properties of rubber, but are hard, inelastic, and more or less brittle.

The amount of resin in latex varies not only in the different rubber-yielding plants, but also to a greater or less degree in the same species according to the age of the tree. In general it may be stated that the latex from the stem of a very young tree will be more resinous than that from an older tree, *i.e.* the amount of resin in the latex tends to diminish with the age of the tree. This variation in the composition of the latex, and consequently of the rubber, due to the age of the tree, is much more marked in the case of certain species than in others. Thus Weber obtained the following results in some experiments with Castilloa trees in Central America:

	Percentage of resin in rubber.
Rubber from Castilloa tree 2 years old	42·33
,, ,, ,, 3 ,, ,,	35·02
,, ,, ,, 4 ,, ,,	26·47
,, ,, ,, 5 ,, ,,	18·18
,, ,, ,, 7 ,, ,,	11·59
,, ,, ,, 8 ,, ,,	7·21

It will be seen from these figures that there is a gradual diminution in the proportion of resin from 42·3 to 7·2 per cent. as the trees increase in age.

The following figures, illustrating the same point in connection with Castilloa trees growing in Trinidad, have been published by the Department of Agriculture in that Colony:

	Percentage of resin in rubber.
Castilloa trees 3 years old	53·99
,, ,, 7 to 8 years old	28·60
,, ,, ,, ,, ,,	26·93
,, ,, ,, ,, ,,	27·09
,, ,, ,, ,, ,,	27·31
,, ,, 15 years old	13·42
,, ,, ,, ,, ,,	11·37

Analyses made at the Imperial Institute of a number of specimens of Castilloa rubber from Trinidad and Tobago have also shown a general diminution in the percentage of resin as the trees increase in age; but, as will be seen from the following figures, the rubber of older trees sometimes contains more resin than that from younger plants:

	Percentage of resin in rubber.
Castilloa trees, 4 years old	64·1
,, ,, 4½ ,, ,,	52·6
,, ,, ,, ,, ,,	56·2
,, ,, ,, ,, ,,	49·3
,, ,, 7½ ,, ,,	52·0
,, ,, ,, ,, ,,	36·9
,, ,, 12 ,, ,, and over	8·3
,, ,, over 12 years old	13·8
,, ,, 17 years old	23·0

In the case of Para trees, however, the composition of the rubber is much less affected by the age of the trees, and the following analyses by Bamber of rubber derived

in Ceylon from Para trees varying from two to thirty years old may be quoted:

	2 years.	4 years.	6 years.	8 years.	10–12 yrs.	30 years.
Moisture . .	0·70	0·65	0·55	0·85	0·20	0·50
Caoutchouc . .	91·20	94·58	94·79	94·60	94·35	93·24
Resin . . .	3·60	2·72	2·75	2·66	2·26	2·32
Protein . .	4·00	1·75	1·51	1·75	2·97	3·69
Ash . . .	0·50	0·30	0·40	0·14	0·22	0·25

From these results it would appear that the rubber from two-year-old Para trees contains only about 1 per cent. more resin than that from the older trees, and that there is little variation in the proximate composition of the rubber obtained from trees of four years and over. This latter conclusion is also supported by the following analyses made at the Imperial Institute of specimens of rubber from the Federated Malay States which were prepared from Para trees aged four and a half, nine, and seventeen years respectively:

	4½ years.	9 years.	17 years.
Caoutchouc	94·18	94·21	95·46
Resin	2·73	2·67	1·59
Protein	2·88	2·89	2·52
Ash	0·21	0·23	0·43

It must, however, be pointed out that although Para rubber derived from young trees may have the same composition as the product from older trees, as determined by the present methods of proximate analysis, it is usually deficient in physical properties, being soft and weak. As a general rule, therefore, it is not advisable to tap very young specimens of any rubber-yielding plant.

A further point in connection with the amount of resin in latex is that in mature trees the latex of the branches and twigs may contain more resin than that of the trunk of the same tree. This fact is illustrated by the following results of experiments conducted by Weber on a Castilloa tree in Central America:

	Percentage of resin present.
Rubber obtained from trunk	2·61
,, ,, ,, largest branches	3·77
,, ,, ,, medium branches	4·88
,, ,, ,, young branches	5·86
,, ,, ,, leaves	7·50

In this tree, therefore, the rubber prepared from the trunk contained the lowest percentage of resin, and there was a gradual increase in the proportion of resin on passing upwards to the leaves, the product from which contained nearly three times as much resin as that from the trunk.

Beadle and Stevens examined a specimen of rubber obtained from the stalks of the leaves of a Para tree and found it to have the following composition:

	Per cent.
Caoutchouc	78·67
Resin	7·12
Protein	13·02
Ash	1·19

In this case also the product obtained from the leaves was much more resinous than the rubber prepared from the trunk of the tree.

In connection with this point reference may be made to an experiment conducted by Burgess to determine the variation in the amount of resin in the rubber from different parts of a Para tree. Three specimens of rubber were prepared from the tree in the following manner: (1) from a large root, (2) from the basal portion of the trunk up to 2 ft. from the ground; and (3) from the trunk at a height of 20 ft. It was found in this case that the proportion of resin was greatest in the rubber from the root and least in that obtained at a height of 20 ft. on the trunk.

Protein.—The nitrogenous substances present in latex and crude rubber are generally assumed to be proteins, and their amount is calculated in the usual way from the percentage of nitrogen. It is extremely

probable, however, that other compounds containing nitrogen may also be present.

The amount of protein in latex derived from different plants, and in the rubber prepared therefrom, shows considerable variation, as in the case of the resin. The following analyses made at the Imperial Institute will illustrate the variation in the proportion of protein present in different crude rubbers :

	Landolphia owariensis.	*Landolphia Heudelotii.*		Para rubber.		Ceara rubber.		Funtumia rubber.	
	Biscuits.	Sheet.	Balls.	Sheet.	Sheet.	Biscuit.	Scrap.	Sheet.	Biscuit
Caoutchouc	93·7	93·8	91·3	96·5	94·8	92·2	70·8	90·3	79·5
Resin .	5·6	5·9	5·9	1·9	1·8	3·1	4·6	7·7	10·5
Protein .	0·4	0·1	1·4	1·4	3·1	3·4	21·4	1·7	9·3
Ash .	0·3	0·2	1·4	0·2	0·3	1·3	3·2	0·3	0·7

These analyses show that the amount of protein present in various rubbers may vary from 0·1 per cent. in the case of a specimen of *Landolphia Heudelotii* sheet to no less than 20·4 per cent. in a specimen of Ceara scrap rubber. Ceara latex usually contains a large proportion of protein, the bulk of which finds its way into the rubber if this is collected in the form of scrap by the spontaneous coagulation of the latex on the stem. If, however, Ceara rubber is prepared in the form of biscuits by diluting the latex and allowing it to stand until coagulation takes place, a considerable amount of the protein remains behind in the liquid. The rubber prepared in biscuit or sheet from the latices of certain species of Landolphia is noteworthy in containing a very small amount of protein, much less in fact than is present in the finest plantation Para rubber.

CARBOHYDRATES.—Small quantities of carbohydrates (inosite and its derivatives) have been isolated from certain kinds of crude rubber from the Gaboon, Borneo, and Madagascar, the amount usually present not exceeding 0·5 per cent. Recently, however, specimens of Para rubber prepared by the Brazilian method at the Botanic Gardens, Singapore, were found on examination at the Imperial Institute to contain from 1·0 to 2·7 per cent. of a saccharine substance which was identified as

laevo-methylinosite. This substance was found to occur to the extent of 0·46 per cent. in the latex of the tree from which the rubber was obtained. Its presence in fine hard Para from South America was also proved.*

MINERAL MATTER.—A portion of the mineral matter present in the latex invariably finds its way into the crude rubber and is left in the form of ash when the rubber is incinerated. The quantity of ash in plantation Para rubber does not usually exceed 0·5 per cent., whereas in the case of rubber prepared by natives, such as Landolphia balls, there may be ten times this amount or even more, owing to the admixture of earthy impurities. According to Henriques, the bases usually present in the ash of rubber are lime, magnesia, alumina, and iron. Spence has recorded that the ash which he obtained from a sample of the latex of *Funtumia elastica* contained potassium, iron, calcium, and magnesium, which were present in the latex chiefly as phosphate, sulphate, and oxalate; the total amount of ash was 0·266 per cent. on the latex and more than three-fourths of it consisted of soluble potassium salts.

Function of Latex.—In concluding this chapter a brief summary may be given of the views which have been advanced as to the function of latex in the plant. In the first place it may be again noted that latex is not universally met with in plants, but is confined to certain orders only, so that it cannot be regarded as essential to plant life. Again laticiferous plants differ widely in character and in the conditions under which they grow, and as we have already seen, some of them produce a rubber-yielding latex whereas others do not. The latex is therefore very variable in composition, and it is possible that its function may not always be the same in every plant.

It has been suggested that the latex serves for the purpose of storing water for use by the plant during drought, and this may perhaps be true of those laticiferous plants which inhabit countries having a well-marked dry season. Many laticiferous plants, however, are found in countries and situations where there is always abundant moisture, and in these cases it would appear

* See paper by S. S. Pickles and B. W. Whitfeild in *Proceedings of the Chemical Society*, 1911, vol. xxvii. p. 54.

unnecessary for the plant to secrete latex in order to have a reserve supply of water.

Another suggestion is that the latex forms a reserve food-supply or that it serves to conduct food-materials in the plant. In support of this view it is pointed out that latex usually contains protein and carbohydrates, and that in certain cases it is known to contain a proteolytic ferment capable of rendering the protein soluble so that it can be utilised as food by the plant.

Other views are that the latex serves for the storage of waste products, the rubber being regarded in this case as a waste product, or that it forms a protection to the plant by sealing incisions made in their bark, thus preventing the entry of insect or fungoid pests.

None of these views has, however, received general acceptance, and it is quite possible that the primary function of latex may vary in different plants.

CHAPTER V

THE TAPPING OF RUBBER PLANTS

General Principles.—The latex of rubber plants is usually obtained by making incisions in the bark with a sharp instrument, the method of "incision," or by removing portions of the bark, the method of "excision." By either of these methods a number of the laticiferous vessels are opened and from these the latex exudes. Owing to the continuous nature of the vessels, and to their intercommunication in many cases, a single cut serves to drain the latex from a considerable area of bark. If, however, the latex is contained in isolated cells, it is not so easily obtained by tapping, and in the case of the Guayule plant, which exhibits this feature, the rubber is extracted by mechanical methods or by treatment with solvents.

In order to understand the problems involved in the tapping of rubber trees, it will be advantageous in the first place to consider briefly the structure of the stem and the functions of the different parts.

The stem of a mature tree may be divided into the following parts: (1) the bark, (2) the wood, and (3) the pith, which, however, is usually obliterated in old trees.

The bark as thus understood is the portion which can be readily stripped off from the wood, and it includes not only the true bark, *i.e.* the external corky layers, but also the tissue known as the cortex, which plays a very important part in the life-processes of the plant.

Between the cortex and the wood there is a single layer of actively dividing cells, known as the cambium, and the cells cut off from the cambium externally form additions to the cortex (the tissue thus produced being known as bast), whilst those cut off internally give rise to wood. The tissues produced in this way from the cam-

bium are known as secondary wood and secondary bast, to distinguish them from the primary wood and bast of the young shoots which are developed from the meristematic tissue situated at the growing point of the stem. The primary structure is only seen in the green portion of the stem within a short distance from the growing point; in the older portions secondary thickening will have commenced, and the formation of wood and bast by the cambium, with the consequent increase in the girth of the stem, results sooner or later in the disorganisation of the external primary cortex. The "bark" of rubber trees when ready for tapping is consequently composed of secondary cortex, and it is the laticiferous vessels developed in this tissue which are of practical importance to the rubber planter.

In the secondary cortex the laticiferous vessels run in a longitudinal direction, *i.e.* parallel to the axis of the stem, and they are most numerous in the inner layers near the cambium, where they are arranged in series of concentric rings encircling the stem. The generally accepted view of the origin of these vessels is that, like the vessels of the wood and the sieve-tubes of the bast, they are formed from rows of special cells produced by the cambium. The cells cut off from the cambium which are destined to develop into laticiferous vessels are arranged in longitudinal rows, and at a very early stage the transverse walls dividing them are absorbed with the formation of a continuous tube which soon becomes filled with latex. According to this view, the laticiferous vessels in the secondary cortex are produced solely by the cambium, which is continually adding fresh layers to the inner side of the cortex to replace the exhausted tissue of the external layers.

This opinion regarding the development of the laticiferous tissue is, however, contested by Wright, who asserts that the vessels are formed *de novo* in the cortex by the absorption of the walls of ordinary cortical cells.

With reference to the functions of the wood and cortex it may be briefly stated that the vessels of the wood serve to conduct an upward current of water, containing various substances in solution, from the roots to the leaves, whilst the sieve-tubes of the cortex conduct a downward current of liquid, containing food-products

elaborated in the leaves, to all parts of the plant, including the roots. The sieve-tubes of the cortex which serve as channels for the transmission of the food-products are quite distinct from the laticiferous vessels.

It will be evident from the preceding account that when incisions are made in the bark of a rubber tree there is a possibility of causing damage to the cambium if the cut penetrates too deeply, and that whatever method of tapping is employed, some interference with the transference of nutritive material in the plant will be caused.

The laticiferous vessels are most numerous in the inner layers of the cortex, and it is therefore essential, in order to obtain a good flow of latex, that the incisions should be sufficiently deep. On the other hand, care must be taken that the cuts do not unduly penetrate or expose the wood, as this will injure the cambium and thus retard, or even prevent, the formation of the new tissue required to heal the wounds.

It is, of course, impossible in practice to tap the inner layers of the cortex without occasionally penetrating to the wood, but with the exercise of care the damage to the cambium can be reduced to a minimum and no permanent harm will result. If, however, a large area of wood is exposed by tapping, as is frequently the case in native methods, a portion of the cambium is destroyed and the new tissue required to cover the wound can only be formed by an ingrowth from the surrounding undamaged cambium. In such cases the healing of the bark may not be complete, thus affording an entrance to insect and fungoid pests, or the considerable growth of new tissue required to repair the damage may result in the formation of excrescences on the stem which interfere with subsequent tappings.

With reference to the possible effect of continued tapping on the distribution of the food-supply in the plant it may be recalled that if a complete ring of bark of sufficient width be removed from a tree, the part below the incision is cut off from the descending stream of nutritive material in the cortex, and that as soon as the reserve food-supply stored in the plant below the incision is exhausted, the roots will be unable to obtain the necessary nourishment and the tree will ultimately

die. The effect of thus "girdling" a tree represents the maximum interference with the vital functions of the plant which can be caused by tapping, but all incisions made in the bark will interrupt the transference of food-substances in the plant to a greater or less degree, depending on the number, depth, and arrangement of the cuts. The question therefore arises as to the extent to which different tapping systems affect the vitality of the tree, and whether the continued use of any method, adopted probably without any regard for physiological considerations, is likely to cause permanent damage to the trees, or by depleting the food-supply interfere with the formation of fresh latex. This problem, which is of the highest importance in connection with the methods to be adopted on rubber plantations, has been investigated, so far as *Hevea brasiliensis* is concerned, by Professor Hans Fitting* in Java, and his results have attracted considerable attention amongst rubber planters.

Fitting's Researches.—It is not possible here to deal in detail with Fitting's work, but a brief summary of his experiments and conclusions may be given. He endeavoured to ascertain the probable effects of different methods of tapping on the vitality of Para trees by investigating their influence on the reserve food-supply stored in the tissues. He found that the effect of girdling Hevea trees was to cause an accumulation of reserve food-material (starch) above the wound, whereas below the wound the reserve supply of starch in the tissues was very quickly depleted in the case of young trees and more slowly in older trees, the result in each case being that a deficiency of food-material occurred sooner or later at the base of the tree. A similar effect was observed as the result of making an oblique spiral incision extending over the entire circumference of the stem, thereby interrupting the longitudinal course of the sieve-tubes in the bark. In this case communication between the bark above and below the incision is possible in an oblique direction, but this is apparently not sufficient to convey an adequate supply of fresh food-material from above to the base of the tree. In a further experiment the half-herringbone system of tapping, with six lateral cuts, was employed, and the tapped area only extended

* *Beihefte zum Tropenpflanzer*, 1909.

over one-fourth of the circumference. After tapping for five months, by means of the Bowman-Northway parer or the parer and pricker alternately, the distribution of starch in the stem was determined. It was found that no starch or reducing sugar was present in the zone of bark within 2 in. of the top or sides of the uppermost incision, but that above this area the bark and wood contained abundant starch; that no starch or reducing sugar occurred in the strips of bark between the incisions, although starch was present in the wood below; that starch could not be detected in the bark within a distance of 6 in. below the lowest cut; and that no starch or sugar was present in the renewed bark on the incisions nor in the outer layers of the wood below. In all other parts of the stem there was an abundant supply of starch. This method of tapping has therefore only a local influence on the distribution of food-materials in the stem, and is not likely to affect adversely the vitality of the tree.

From the results of his experiments Fitting concluded that, in the case of young trees especially, the full spiral method of tapping cannot be recommended, nor indeed any other system in which the incisions cover practically the whole of the circumference of the stem without leaving continuous vertical strips of untapped bark, sufficiently wide to maintain the necessary connection between the crown and the base of the tree. He suggested that the safest and most rational plan would be to divide the tappable surface of the stem into four vertical sections, and to tap each of these in rotation by the half- or full-herringbone system, each section serving for a year's tapping. In the second year the quarter opposite to the first would be tapped, and then the others in rotation. In this way four years would elapse before it was necessary to tap the renewed bark on the first quarter, and sufficient connecting strips of untapped original or renewed bark would always be maintained to carry on the vital functions of the plant. In the case of large trees the stem can be divided into eight vertical sections and the two opposite sections tapped simultaneously in rotation.

Fitting also drew attention to the advisability of allowing the trees to rest between successive tapping periods in order that the reserve food-supply, which will

have been depleted more or less by the previous tapping, may be replenished, as otherwise each successive tapping period will leave the reserve food-supply more and more exhausted with the possibility of injury to the tree or deterioration in the quality of the latex. He further expressed the opinion that an interval of rest during a tapping period would in many cases be beneficial to the trees. Another point which he considered of importance was that it will be inadvisable to tap renewed bark until it has regained its normal condition as evidenced by the presence of starch in the cells.

This work of Fitting has served to emphasise the necessity of considering the probable physiological effects of the continued use of any system of tapping before advocating its adoption on a large scale, and some of the points which he raised, such as the necessity for periods of rest for the trees, may become of considerable importance when plantation trees have been tapped sufficiently long for the full effects of the tapping system employed to become apparent. Mr. E. Bateson, Assistant Mycologist in the Federated Malay States, has been conducting further experiments, on the lines suggested by Professor Fitting, on the depletion of the food-reserves of Para trees by tapping and the effect upon the vitality of the trees. It is stated that the research has brought some interesting facts to light which it is expected will have a direct bearing on many questions connected with tapping, but the detailed results have not yet been published.*

The plan of dividing the stem into four or more vertical sections and tapping these in rotation has been widely adopted on plantations, and is now the most general method of tapping Para trees. This system, it may be mentioned, had been advocated by Ridley, and in a modified form by Wright, before the results of Fitting's experiments were published, in order to ensure that the renewed bark should not be tapped until four years old.

Tapping Systems.—A brief review of the principal methods employed in tapping rubber trees may now be

* *Reports of Director of Agriculture, Federated Malay States*, for 1911 and 1912. See also paper by Dr. S. V. Simon in *Der Tropenpflanzer*, 1913, pp. 63, 119, and 181.

given, reserving a more detailed account until dealing with the particular plants to which they are specially applicable.

Rubber is usually prepared by tapping the stems of the living plants and subsequently coagulating the latex thus obtained. In certain cases, however, the natives of parts of Africa and America frequently fell the trees or cut down the vines in order to obtain the rubber. This plan is employed in preparing the rubber of *Funtumia elastica* in parts of West Africa, and very commonly throughout Central Africa for obtaining the rubber from Landolphia and other vines; it is also generally adopted by the natives in the Amazon valley for preparing the rubber of *Castilloa Ulei*. After felling the trees, the natives either extract the latex by making numerous circular incisions extending right round the trunk, or they allow the bark to dry, then strip it from the stem and prepare the rubber from it by a process of beating. The stems of the vines are usually cut into short lengths and the latex allowed to drain out, a further quantity of rubber being obtained in some cases by beating the dried bark. This method of felling the trees is very destructive and speedily leads to their extermination.

Turning to the tapping processes, there are a large number of different methods of making the incisions. In some cases, as already mentioned, incisions are made in the bark by means of a sharp instrument, and no bark is cut out (the method of "incision"); whilst in other processes portions of the bark are removed in forming the cuts (the method of "excision"). Examples of native incision methods are seen in the tapping of *Hevea brasiliensis* by means of a small axe with a very short cutting edge, and of *Castilloa elastica* by means of a machete. Native excision methods, on the other hand, are illustrated by the tapping of *Funtumia elastica* by means of a native gouge, and by the removal of large slices of bark from Landolphia vines.

As the laticiferous vessels run longitudinally in the cortex, it is evident that a transverse (horizontal) incision will open many more vessels than a longitudinal (vertical) cut. A horizontal incision is, however, not well adapted for the collection of the latex, as it does not form a channel along which the latex can flow. The result of using

horizontal incisions is that the latex exudes from the cuts and then runs down the stem, and the method is chiefly employed in those cases where the latex coagulates spontaneously and quickly on exposure to air. In practice the incisions are usually made obliquely to the axis of the stem at angles of from 45° to 60° with the horizontal; the latex runs down the channel thus formed and its collection is greatly facilitated. In some cases vertical incisions have been employed for tapping purposes, and frequently a number of oblique incisions are connected by a vertical channel which serves to collect the latex from all of them.

The principal systems of tapping may be grouped under the following heads: (1) single oblique incisions; (2) V incisions; (3) basal V or Y incisions; (4) herring-bone incisions (half or full); (5) spiral incisions (half or full); (6) horizontal incisions; and (7) vertical incisions.

(1) *Single Oblique Incisions.*—In this system a number of oblique incisions, varying in length according to the circumference of the stem, and also in the distance apart, are made one above the other in a vertical row on the stem. A cup to receive the latex has to be fixed at the base of each cut (see fig. I, p. 67).

Sometimes the cuts are made to overlap instead of being in the same vertical line, so that the latex from the top cut, having reached the lower end of the incision, runs down the stem into the incision below, and so on. Only a single cup at the base of the lowest cut is then required to collect the latex.

(2) V *Incisions.*—This type of incision is made by combining two oblique cuts so as to form a V. The size of the V's may vary considerably, the side cuts ranging from 1 to 12 in. or more in length. Usually the V's are arranged in vertical rows on the stem to a height of 6 ft. or more, and fresh V's are subsequently made at the side of the previous row.

Cups have to be fixed at the base of each V, as in the case of the single oblique cuts, but only one cup is required for two cuts, instead of one for each (see fig. II, p. 67).

The yield from a V cut is usually a little less than from two separate oblique incisions of the same size.

(3) *Basal* V *or* Y *Incisions.*—This system has been

adopted for young plantation Para trees which have only attained a sufficient size for tapping at the base of the stem. Either an ordinary V incision, or a Y, which is a V with a vertical channel below, is made at the base of the stem.

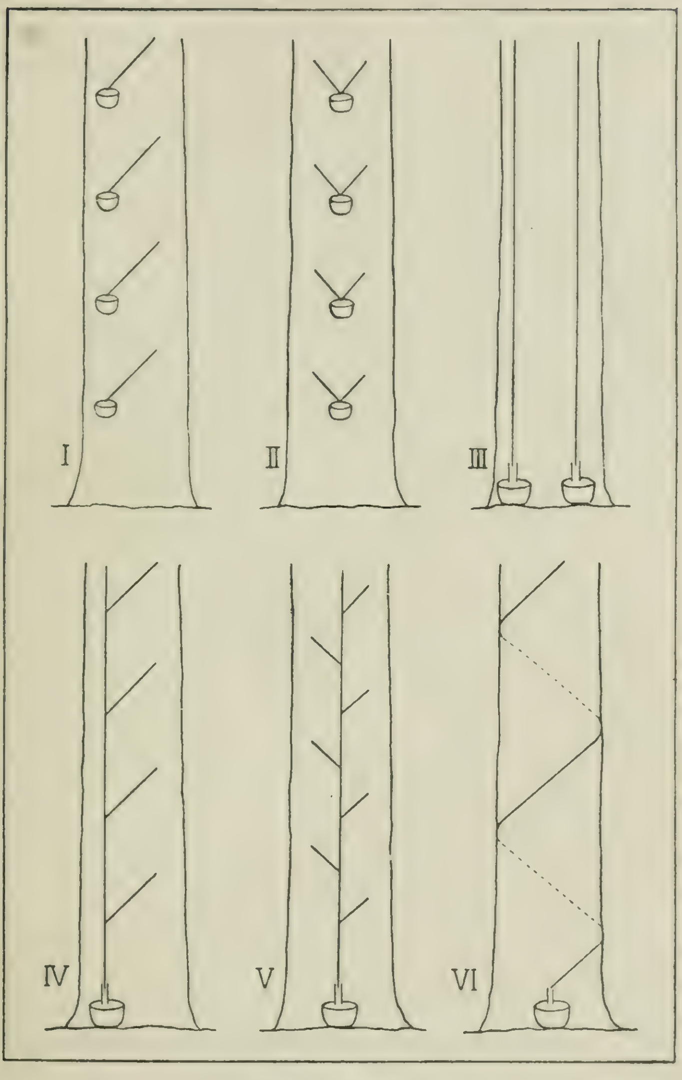
(4) *Herringbone Incisions.*—This system consists of a series of single oblique incisions joined together at their lower ends by a vertical conducting channel for the latex. If the lateral incisions are all on one side of the vertical channel (see fig. IV, p. 67) it is called the half-herringbone system, whilst if they are on both sides (see fig. V, p. 67) it is the full- or double-herringbone system. In the latter case it is better to make the lateral cuts on opposite sides of the vertical channel alternately, as in the figure, and not at the same level, so as to avoid the formation of a large wound at the junction of the three cuts. A single cup placed at the base of the vertical channel collects the latex from all the incisions.

(5) *Spiral Incisions.*—A full spiral incision is a long oblique cut which completely encircles the stem one or more times according to the angle at which it is made. Sometimes two or more spirals are cut on a large tree. Only a single cup is required at the base of each incision (see fig. VI, p. 67). The full spiral system is not usually employed now on plantations. If the cuts are shorter and do not encircle the entire stem, the system is spoken of as the half spiral, and simply consists of a series of elongated oblique cuts which each require a collecting cup to be affixed at their lower end.

(6) *Horizontal Incisions.*—This system is usually only employed in those cases in which the latex is allowed to coagulate on the stem. In tapping the Ceara tree, for example, a large number of small horizontal incisions are often made by stabbing the stem with the end of a thin knife about 1 in. in width.

(7) *Vertical Incisions.*—Long vertical incisions (see fig. III, p. 67) have been used for tapping *Funtumia elastica* trees in West Africa and have given very fair yields of latex. Recently Bamber has suggested a method of tapping Hevea trees by means of vertical incisions.

Reopening the Incisions.—In concluding this summary of the different tapping systems, mention must be made of the practice of reopening the incisions which has been



TAPPING SYSTEMS.

I. Single oblique incisions.
II. V incisions.
III. Long vertical incisions.
IV. Single herringbone incisions.
V. Double herringbone incisions.
VI. Spiral incisions.

adopted in certain cases, notably in tapping Hevea trees. It has been found that if the initial incisions made in tapping Hevea trees are reopened, either by cutting off a thin shaving of bark from the lower edge of the incision or by means of a pricking instrument, a further flow of latex occurs, and that the process may be repeated every day or every alternate day for long periods. This response to repeated tapping is one of the characteristic features of *Hevea brasiliensis* and forms one of its great advantages for plantation purposes. The Ceara tree sometimes shows a similar response when growing under suitable conditions. In other trees, however, such as *Funtumia elastica*, the whole of the available latex can be obtained at the first tapping and no further yield results on reopening the cuts. Additional details regarding this method are given in the chapter specially devoted to the Para tree.

CHAPTER VI

THE PREPARATION OF RUBBER

Coagulation of the Latex.—In order to obtain rubber from latex, it is necessary to induce the change known as coagulation. When coagulation takes place, the caoutchouc globules present in the latex coalesce to form a white clot of soft porous rubber which separates from the liquid and rises to the surface, leaving the serum perfectly clear if the process is complete. In the case of some latices an intermediate stage can be obtained in which the rubber globules separate from the liquid without coalescing, and rise to the surface as a "cream," which can be again diffused through the liquid on shaking. This behaviour, which is termed "creaming," is, however, not general, and is only shown by certain latices, such as that of *Castilloa elastica*. If the creamed globules are separated from the liquid and submitted to pressure or allowed to dry, they coalesce to form a mass of rubber similar to that obtained by direct coagulation.

The exact nature of the change which takes place during the coagulation process is not fully understood, but the most reasonable hypothesis appears to be that some alteration occurs in the substance composing the globules of the latex. It seems probable that the globules do not consist of solid particles of rubber, but of a liquid substance, and that when coagulation occurs this liquid undergoes polymerisation or condensation with the production of solid rubber (see Dunstan, *Bull. Imp. Inst.*, iv. 323).

A careful study of the physical changes which take place during the coagulation of latex has been made by Victor Henri, who has obtained very interesting results. He has found, for example, that when acetic acid is added to Para latex in insufficient amount to produce coagulation, the Brownian movement of the globules is almost

completely arrested so as to be hardly perceptible. If more acid be added, the globules commence to unite and form files of greater or less length, which then join up to produce a fine network of rubber. The particular form which this network assumes varies with the coagulant used, and in Henri's opinion the strength of the rubber is largely influenced by the structure of the clot and hence by the method of coagulation employed. A number of investigators have published results which support the view that the method of preparation has considerable effect on the strength of the rubber; but it seems impossible that the physical properties of the vulcanised product can depend on the structure of the crude rubber, as this must be entirely destroyed in the mixing which precedes vulcanisation.

Methods of Coagulation.—Coagulation can be brought about in very many ways, which, however, are not all of universal application. A method which will readily coagulate the latex from one plant may have no effect whatever upon that from another, so that the process employed must always be adapted to the particular latex which is being treated.

The principal methods of inducing coagulation, which are of practical importance, are given in the following account:

(1) *Spontaneous Coagulation.*—Some latices undergo spontaneous coagulation on exposure to the air for longer or shorter periods. The latex of many Landolphia vines, and frequently that of the Ceara tree, does not flow freely from the incisions and coagulation quickly occurs upon the stem, films of rubber being formed which are subsequently stripped off and made either into balls or loose "scrap."

Other latices which flow more freely from the plant so that they can be collected in bulk also coagulate spontaneously more or less completely on standing. Natives frequently pour latex into holes in the ground, or into a hollow tree, or into vessels, and leave it to stand until coagulation takes place. In those cases, however, in which the coagulation does not occur rapidly the protein constituents of the latex are liable to undergo decomposition, with the result that the rubber acquires a very disagreeable odour.

(2) *Dilution of the Latex with Water and allowing it to Stand.*—This method can be conveniently used for the preparation of Ceara rubber if the latex flows sufficiently freely to be collected in bulk. The latex is simply diluted with water and allowed to stand for twenty-four hours or so, until coagulation occurs.

In the case of some latices dilution with water often retards coagulation indefinitely.

(3) *Dilution of the Latex with Water and "Creaming."*—This process is specially applicable to Castilloa latex, which creams very readily. The latex is diluted with water and is allowed to stand until the "cream," consisting of the rubber globules, rises to the surface. The liquid is run off as completely as possible from the cream, which is then washed by shaking it up with a fresh quantity of water and allowed to separate as before. This treatment may be repeated several times if desired. The cream is afterwards converted into solid rubber by pressure, by centrifugalising, or by allowing it to dry on wire or calico frames.

(4) *Centrifugal Methods.*—In some cases the latex can be quickly and conveniently coagulated by spinning it in a centrifugal machine. This method is chiefly applicable to those latices which cream readily, such as Castilloa latex. Special forms of centrifugal machines have been introduced for treating rubber latex.

(5) *Action of Heat.*—A large number of latices are coagulated by the application of heat, some requiring to be only gently warmed whilst others have to be boiled before the change occurs. Whenever heat is employed to bring about coagulation, great care should be taken to avoid overheating the rubber, as if this occurs the product becomes permanently sticky and depreciated in value. If direct heat be used it is advisable to dilute the latex with water, especially if it is at all thick, and to keep it well stirred during the heating; the rubber may be removed from the liquid in small portions as it separates, and the heating continued until the milkiness of the liquid has disappeared. Other methods of preventing overheating which are sometimes applicable are (1) to immerse the vessel containing the latex in boiling water; (2) to pour the undiluted latex slowly into a large quantity of boiling water; or (3) to pass steam into the latex.

In the Amazon valley the natives coagulate the latex of the Para tree by exposing it in thin layers to the smoke given off by burning palm-nuts. The coagulation of the latex is probably effected partly by the heat and partly by the action of the acetic acid present in the smoke (see below).

The natives of some parts of Africa obtain a similar result by spreading Landolphia latex over their arms and chest, when it quickly coagulates, forming a film of rubber which is then stripped off.

(6) *Action of Reagents.*—The coagulation of latex can be brought about by a large number of chemical agents, and it will only be possible to notice here the methods which are in common use for the preparation of rubber.

Acids.—Many latices coagulate almost immediately on the addition of small quantities of mineral or organic acids. The spontaneous coagulation which frequently occurs when latex is allowed to stand is often due to the acidity which develops in the latex. Organic acids are generally preferable to mineral acids for the preparation of rubber, and acetic, citric, and tannic acids are chiefly used for the purpose. The latex obtained from cultivated Para trees in the East is coagulated almost entirely by the addition of small quantities of acetic acid; formic acid and hydrofluoric acid (purub) are also used. In Africa many Landolphia latices are coagulated by means of the acid juices of fruits or by acid infusions made from species of Costus, Hibiscus, and Tamarindus. The latex of *Funtumia elastica* is not affected by the addition of acetic or citric acid, but it may be quickly and conveniently coagulated by means of a hot solution of tannic acid. A hot infusion of the leaves of *Bauhinia reticulata*, which contain tannic acid (tannin), is employed in parts of West Africa as a coagulant for Funtumia latex.

Salts.—Many salts, such as sodium chloride (common salt), alum, cream of tartar, mercuric chloride (corrosive sublimate), sodium sulphate, and magnesium sulphate, effect the coagulation of latex. A solution of salt is used by the natives in Africa to coagulate the latex of species of Landolphia; alum is commonly adopted in South America for the preparation of the rubber of *Hancornia speciosa*; cream of tartar has been used for preparing

Para rubber in Ceylon ; and mercuric chloride for coagulating Funtumia latex.

Alkaline liquids, such as a solution of soap or wood ashes, are sometimes employed for coagulating certain latices. In some parts of Central America the natives employ a solution of soap for preparing Castilloa rubber.

Alcohol and acetone readily and completely coagulate latex, but their use for the purpose is restricted to the laboratory.

The special applications of these general methods of coagulation to the latex of particular plants will be dealt with in succeeding chapters.

Mechanical Methods of Preparing Rubber.—In many parts of Africa the natives prepare rubber by beating the bark of the underground stems (rhizomes) of certain species of Landolphia and Clitandra, or of the stems and roots of rubber vines. The stems or roots are first allowed to dry thoroughly, in order that the latex may be completely coagulated. The bark is then stripped off and submitted to a beating process, whereby a portion of the bark is eliminated and the threads of rubber become aggregated into a mass. The crude product thus obtained is well washed to remove the loose fragments of bark, and after being softened by immersion in hot water it is again beaten, the treatment being repeated until the rubber is sufficiently free from vegetable matter (see p. 195). Rubber prepared in this way is generally classed as "root rubber."

Machines have been constructed on a similar principle for the extraction of rubber from bark by mechanical means, and also for the preparation of rubber from the Guayule plant.

Extraction of Rubber by Solvents.—This method is principally employed at the present time for the extraction of rubber from the Guayule plant, in which the latex occurs in isolated cells and can therefore not be obtained by tapping. The dried plants are crushed and then treated with a suitable solvent which removes the rubber. The greater part of the solvent is afterwards recovered by distillation and the rubber obtained is purified.

Forms in which Rubber is Prepared.—Freshly coagulated rubber is a white, opaque, porous mass which holds a considerable quantity of the serum of the latex in its

cavities. It is at first quite soft and can be readily torn, but if allowed to stand for some time or if submitted to pressure in order to squeeze out the contained liquid its tenacity increases and it assumes the well-known physical properties of rubber. On drying, rubber becomes translucent and develops more or less colour, the commercial product varying from a very pale straw colour to black. The development of the colour appears to be due to the action of oxidising enzymes present in the latex.

The form in which rubber is prepared by natives varies widely according to the botanical source and the country of origin. Thus Para rubber from South America comes on the market in large, rounded masses, which have a strong smoky odour ; Funtumia rubber from Africa and Castilloa rubber from Central America are prepared in the form of cakes or lumps which are often of considerable size ; the Landolphia rubbers, again, are commonly made into balls of various sizes, or into spindle-shaped or sausage-shaped pieces, or into small cubes (see Plate I). Most of the commercial rubbers prepared by natives have distinctive forms which do not vary.

On plantations the rubber is usually prepared either in the form of "biscuits" or sheet, or, by means of machinery, as sheet or crêpe. The manufacture of biscuits is a convenient method when only small amounts of rubber are being obtained daily; but when larger quantities have to be dealt with, the use of machinery becomes essential.

The first step is to strain the latex, diluted with water if necessary, in order to remove all solid impurities. This is accomplished by passing it through sieves of fine wire gauze or cloth, or by means of a centrifugal strainer. In the manufacture of biscuits or sheet a definite quantity of the strained latex is poured into shallow enamelled vessels (which may be round, square, or rectangular) and the requisite amount of a coagulant is added if necessary ; the latex is then allowed to stand until coagulation has occurred and the cake of rubber is found floating on the liquid. The rubber is lifted from the liquid, placed upon a sloping table and pressed, at first with the hands and finally with a wooden roller, in order to remove the water as completely as possible. The cakes are then washed with water and placed upon sloping tables to

FIG. 1.—TYPES OF RUBBER AS PREPARED BY NATIVES

Rows A. and B. Rubber in balls, spindle-shaped and cylindrical pieces, and collected on sticks.

Row C. Lump rubber. An entire block of Gold Coast lump in the centre, and sections from similar lumps at the sides.

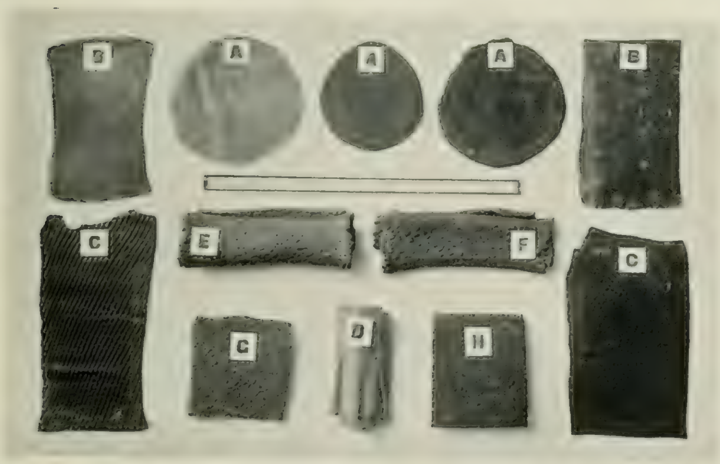


FIG. 2.—TYPES OF PLANTATION RUBBER

A. Biscuits, pale and smoked. B. Sheet, pale and smoked. C. Machine sheet. D. Thin crêpe. E. Thick crêpe. F. Thick crêpe, smoked. G. Block rubber. H. Block rubber, smoked.

drain; whilst still soft they are usually branded with the name of the estate. They are finally transferred to the drying-chamber, where they are spread out on open shelves formed of wire or wooden lattice, or they are hung up on wires until they are perfectly dry. The thin circular cakes obtained in this way are known as "biscuits," whilst the square or rectangular cakes are termed "sheets." This method of preparation is specially suitable for Para and Ceara rubber.

When large quantities of latex have to be dealt with, however, the production of biscuits is rendered impossible owing to the enormous amount of labour involved, and machinery is now generally employed. The strained latex is coagulated in bulk in large tanks by the addition of a suitable reagent, and the freshly coagulated rubber is at once rolled out into sheets by means of a washing-machine similar to those employed in rubber factories. This machine consists essentially of two horizontal steel rollers which rotate at equal or different speeds and can be set at varying distances apart. The rollers are sometimes smooth, but are more generally grooved in order to give a grip on the rubber. A stream of hot or cold water passes between the rollers whilst the rubber is being treated, and thus submits it to a thorough washing. The rubber is passed through the machine several times, the distance between the rollers being gradually reduced until a sheet of the required thickness is obtained. If the rollers are not grooved, smooth sheet is obtained; if the rollers are grooved and rotate at nearly equal speeds, sheets showing the pattern of the rollers are produced; whilst if the rollers are grooved and rotate at unequal speeds, the rubber is subjected to a stretching or tearing action whilst being rolled out and is converted into the corrugated sheet known as crêpe. The advantages of the use of machinery are that large quantities of rubber can be quickly prepared in a form which permits of rapid drying and that the rubber is thoroughly washed in the process.

The crêpe rubber, after drying, is sometimes converted into blocks by submitting it to pressure in steel moulds.

Drying of Rubber.—Freshly prepared rubber always contains a considerable amount of water, the bulk of which should be removed before shipment if the rubber is to

remain in good condition. In some cases in which the rubber is prepared in the form of lump by natives no attempt is made to get rid of the water included in the mass of freshly coagulated rubber, with the result that the lumps remain very porous and have their cavities filled with the serum of the latex ; such rubber reaches the market in a very moist condition and is extremely liable to deteriorate during transit. In certain instances, however, the natives cut the lumps of freshly coagulated rubber into thin strips which are suspended in the roof of a hut, with or without a fire below, and when dry the strips are rolled up into balls or masses of different shapes.

In the case of the balls of Landolphia rubber, which are formed by winding together the thin films of freshly coagulated rubber from the incisions, the drying is sometimes facilitated by cutting the balls open. If this is not done, the rubber in the interior of the ball remains white and opaque, whereas the outer layers become reddish-brown and translucent.

Sometimes the requisite amount of drying is obtained by the method of preparation adopted, as in the case of the smoking process used for Para rubber in South America.

No definite rule can be laid down as to the amount of moisture which may be left in rubber, as the percentage varies very considerably in different forms. In the case of fine hard Para rubber from South America, prepared by the smoking process, which has an antiseptic action, the amount of moisture ranges from 10 to 20 per cent., whereas plantation Para is usually placed upon the market in an almost dry condition, containing, as a rule, less than 1 per cent. of moisture. In all cases, however, the rubber should be dried sufficiently to preserve it from deterioration during transit, as if packed in a too moist condition it will develop mould and become discoloured and injured in appearance.

It is of the utmost importance that rubber should not be exposed to direct sunlight or to too high a temperature during the drying process, as either of these conditions is liable to cause the rubber to become sticky. On plantations special drying-sheds, from which sunlight is excluded, are usually employed. In some cases these consist

merely of well-ventilated sheds, so arranged as to afford a free circulation of air over the rubber. In others a current of dry air, or of hot air at a temperature of 90° to 100° F., is employed to facilitate the drying, and the circulation is maintained by means of a fan. Vacuum driers similar to those used in rubber factories are also employed.

Smoking of Rubber.—Recently large quantities of plantation Para rubber, prepared in sheets, have been subjected to a process of smoking after coagulation. There is a general impression amongst planters that the smoking improves the strength of the rubber, and it is a fact that, as a rule, smoked sheet realises the highest prices at the sales of plantation rubber. The smoking is usually effected in the drying-chamber, either by passing in smoke from a fire placed outside, or by having a fire, suitably enclosed, on the floor of the chamber. The smoke is obtained by burning hard wood, coconut husks, palm husks, and other similar substances.

This method of smoking sheet rubber after coagulation is entirely different from the process employed in Brazil for the preparation of fine hard Para, in which the latex is exposed, in thin films, to the action of the smoke. Machines have, however, been designed for use on plantations which enable the Brazilian process to be imitated, and interesting experiments with these are in progress.

Tackiness of Rubber.—The chief defect which is liable to occur in prepared rubber is the development of the soft, sticky condition known as "tackiness." It has been already pointed out that rubber will become sticky if exposed to sunlight or to too high a temperature during its preparation or subsequently, and many cases of tackiness are, no doubt, due to these causes. In other instances, however, carefully prepared specimens of rubber, which have not been over-heated or exposed to sunlight, become tacky, either as a whole or only in parts, and the causes of this change are very obscure. It has been suggested that the effect is produced by bacteria, and in support of this view it is pointed out that contact with a piece of tacky rubber will induce tackiness in sound rubber. The evidence which has been adduced to prove that the change is due to bacterial action is, however,

not very convincing, and in certain cases a bacteriological examination of tacky rubber has given negative results.

Another suggestion, similar to the above, is that tackiness is produced by the action of certain enzymes, whilst other views are that the method of preparation and the coagulant employed may predispose the rubber to become tacky. The development of stickiness in rubber, other than that produced by heat or sunlight, is, however, occasional rather than general, and it is difficult to explain why one of two pieces of rubber prepared in exactly the same way should develop tackiness whilst the other remains sound, or why one portion of a sample should be affected and another not.

In certain cases apparently the development of tackiness is not associated with any change in the chemical composition of the rubber, as will be seen from the following analyses by Bamber:

	Sound.	Tacky.	Tacky.	Very tacky.
Moisture . . .	0·30	0·36	0·06	0·44
Ash . . .	0·38	0·28	0·54	0·72
Resin . . .	2·36	2·32	2·66	3·70
Protein . . .	3·50	3·85	3·50	4·90
Caoutchouc . .	93·46	93·19	93·24	90·24

In these specimens the sound and tacky rubbers were practically identical in composition, whilst the "very tacky" rubber only contained about 1 per cent. more resin and protein than the others.

On the other hand, an examination made at the Imperial Institute of the sound and tacky portions of a specimen of crêpe rubber from the Federated Malay States showed that the sound portion contained only 2·9 per cent. of resin (acetone extract), whilst the tacky portion contained no less than 8·2 per cent. In this case, therefore, the development of tackiness was associated with a large increase in the amount of resin. No evidence of the presence of volatile or fixed oil in the acetone extract from the tacky portion could be obtained, but it was found to contain a considerable quantity of free acids of resinous nature.

It has been stated that it is the rubber obtained from

the first tappings of a Para tree which is inclined to become tacky, but on the other hand the reverse is the case in the rubber obtained from forest trees of *Sapium Jenmani* in British Guiana. The rubber from the first tapping of these Sapium trees is usually of excellent quality, whereas that from the succeeding tappings steadily deteriorates in physical properties and finally becomes a soft sticky mass.

It will be evident from these facts that the question of tackiness in rubber is by no means simple, and it seems probable that the condition may arise from a variety of different causes.

CHAPTER VII

THE CHEMISTRY OF RUBBER

Composition of Crude Rubber.—Commercial rubber consists essentially of a hydrocarbon (caoutchouc), the true rubber substance, together with varying amounts of resinous and protein substances, mineral matter, and moisture. Small quantities of carbohydrates also occur in certain rubbers.

The rubber collected from wild plants by natives usually contains in addition more or less vegetable matter, in the form of fragments of bark, etc., and sometimes mineral impurities as well. In badly prepared specimens the amounts of these impurities are often very considerable.

Properties of Rubber.—In its purest form, rubber is a practically colourless, highly elastic solid, which according to Weber has a specific gravity of 0·911 at 17° C. It is insoluble in water, but absorbs about one-fourth of its weight of the liquid, swelling considerably. Alcohol and acetone dissolve the resins from crude rubber, but are without solvent action on the hydrocarbon, which, however, absorbs them as in the case of water, and swells. Rubber may be dissolved by carbon disulphide, chloroform, benzene and its homologues, petroleum spirit and turpentine, and usually to a greater or less extent by ether. When rubber is treated with one of these solvents, it swells up, forming a gelatinous mass which slowly dissolves and yields a viscous solution; rubber thus behaves as a colloid substance. On dissolving crude rubber a quantity of an insoluble constituent often remains suspended in the solution, varying in amount according to the variety of rubber. This constituent was formerly termed "insoluble caoutchouc" on the assumption that it is a hydrocarbon like the soluble portion, but analyses made by Weber showed that the

insoluble substance contains a considerable amount of oxygen. More recently Spence has demonstrated that a large proportion of nitrogen is present in the insoluble constituent, and he regards the latter as consisting mainly of protein.

Rubber slowly absorbs oxygen on continued exposure to the air with the formation of a brittle resinous substance which is known as Spiller's resin, from the name of its first investigator.

Action of Heat on Rubber.—When rubber is heated at temperatures above 100° C. it softens and becomes sticky, the effect increasing with rise of temperature, and it afterwards retains these characters on cooling. If heated to a higher temperature, it melts to form a dark brown liquid, which on further heating (above 160° C.) undergoes decomposition with the production of a mixture of liquid hydrocarbons. The liquid thus obtained is a good solvent for rubber.

The destructive distillation of rubber, with the production of this mixture of hydrocarbons, was first carried out by Barnard in 1833, and since that date the products of the reaction have been carefully investigated by a number of chemists. From the liquid obtained by conducting the distillation at the ordinary pressure, the following hydrocarbons have been isolated:

Isoprene (C_5H_8, boiling-point 37°–38° C.), which was first separated and examined by Greville Williams in 1860.

Dipentene ($C_{10}H_{16}$, boiling-point 180°–181° C.) was first obtained in 1835 by Himly, who called it caoutchine, and was afterwards examined by Greville Williams. In 1879 a hydrocarbon (di-isoprene), possessing similar characters to caoutchine, was obtained by Bourchardat by heating isoprene in a sealed tube, and later Wallach showed that this hydrocarbon and caoutchine were identical with dipentene.

Harries has separated two other hydrocarbons from the dipentene fraction of the distillate, one boiling at 147°–150° C. and the other at 168°–169° C.

Heveene.—Bourchardat gave this name to an oil which he separated from the fraction of the distillate boiling above 200° C., but it has never been carefully investigated.

It may be mentioned that Fischer and Harries have found that if the distillation of rubber be conducted in a

vacuum, the chief products are high-boiling hydrocarbons (boiling-point 180° to 300° C. in vacuo), and that only small quantities of isoprene and dipentene are formed. It would appear, therefore, that the isoprene and dipentene obtained when the distillation is conducted at the ordinary pressure are the result of secondary decompositions.

If strongly cooled, rubber loses its elasticity and becomes hard and brittle, but it regains its normal characters on warming.

Chemical Reactions of Caoutchouc.—Caoutchouc is not affected by aqueous or alcoholic solutions of the alkalis.

Hydrochloric acid combines with the hydrocarbon under certain conditions to form addition compounds; by passing moist hydrochloric acid gas into a solution of rubber at the ordinary temperature Weber obtained a product of the empirical formula $C_{10}H_{18}Cl_2$. Hydrobromic acid exerts a similar action, but is not so energetic as hydrochloric acid. Strong nitric acid readily attacks rubber with the production of a yellow colour, and Ditmar, who has carefully studied this reaction, has shown that a definite product is obtained which he has identified as a dinitro-monobasic acid, probably dinitro-hydrocumic acid.

With the halogens (chlorine, bromine, and iodine) caoutchouc forms addition products, some substitution frequently occurring at the same time. The best known of the addition compounds is the tetrabromide ($C_{10}H_{16}Br_4$); this compound is prepared by slowly adding bromine to a well-cooled solution of caoutchouc in chloroform until the bromine is present in excess, and then pouring the liquid into alcohol when the tetrabromide separates in the form of white flakes.

By passing nitrous fumes, obtained by the action of nitric acid on arsenious oxide, into a solution of rubber in light petroleum, Harries succeeded in isolating three different compounds, according to the conditions of the experiment. To these products he gave the name nitrosites. A similar substance was also obtained by Weber on passing dry nitrogen dioxide gas into a solution of rubber in benzene. The formation of these nitrosites has been recommended as a method for the direct estimation of caoutchouc.

Harries has shown that caoutchouc combines with

ozone forming a substance belonging to the group of compounds which he has termed ozonides. A study of the decomposition products of this caoutchouc ozonide has thrown an interesting light on the question of the constitution of the hydrocarbon.

Vulcanisation.—The vulcanisation of rubber may be effected by dipping it in melted sulphur, by heating a mixture of rubber and sulphur, by treating rubber with a solution of sulphur monochloride, or by exposing it to the vapour of sulphur monochloride. In the second method the rubber is mixed with a certain proportion of sulphur, varying in practice from 4 to 40 per cent., according to the class of product required, and is then heated at a temperature usually ranging from 125° to 150° C. Only a portion of the sulphur actually combines with the rubber, the excess remaining in the vulcanised product as free sulphur. In this process the combination of the sulphur with the rubber is greatly facilitated by the presence of certain substances; such as litharge, slaked lime or magnesia.

In vulcanising by means of sulphur chloride the rubber is treated with a solution of this reagent in benzene, containing from 1·5 to 3 per cent. of sulphur chloride, or in special cases the rubber is exposed to the vapour.

Experiments conducted by Weber led him to the conclusion that vulcanisation is brought about by a chemical change, the caoutchouc combining with the sulphur or sulphur chloride to form addition compounds such as $C_{10}H_{16}S_2Cl_2$. More recently, however, it has been suggested by Wolfgang Ostwald that the taking up of sulphur or sulphur chloride by rubber is more probably a case of colloidal adsorption than of chemical change. The discussion as to which of these views best represents the known facts is still proceeding and it is recognised that a combination of both actions may be involved.

Constitution of Caoutchouc.—The hydrocarbon caoutchouc has the empirical formula $C_{10}H_{16}$, being thus similar in composition to oil of turpentine and other terpenes, but at present its molecular weight is unknown and consequently its molecular formula can only be expressed as $(C_{10}H_{16})_x$. It is an optically-inactive, unsaturated hydrocarbon, each $C_{10}H_{16}$ group containing two unsaturated linkages and therefore capable of forming addition

products such as the tetrabromide $C_{10}H_{16}Br_4$. Many attempts have been made to devise a constitutional formula for the $C_{10}H_{16}$ group in caoutchouc which shall agree with all the known facts regarding its chemical behaviour and its close relation to isoprene and the terpenes. Harries, as the result of his work on the ozonide which he obtained from caoutchouc, has suggested that the $C_{10}H_{16}$ group in caoutchouc is a derivative of an eight-carbon ring compound, viz. dimethyl*cyclo*octadiene. Other suggestions regarding the constitution of caoutchouc have been based on the fact that isoprene and the allied hydrocarbons containing two conjugated double linkages readily polymerise with the formation of rubber-like substances. This change may, however, take place in several different ways, and it is therefore impossible to draw definite conclusions as to the constitution of the resulting product.

The constitution of caoutchouc, therefore, remains an open question at the present time, though much information which will be of value in determining the matter is being gradually accumulated.

Synthetic Rubber.—The possibility of manufacturing rubber synthetically by chemical means has attracted much attention during the last few years, but it will only be possible here to give a very brief statement regarding the present position of the problem. In the first place it may be pointed out that what is called "synthetic rubber" is actually rubber, identical with or closely resembling natural caoutchouc in composition, physical properties, and behaviour, but produced chemically, and that it must not be confused with the group of products known as "rubber substitutes."

The preparation of rubber synthetically on a commercial scale has been a possibility, or even a probability, since it was first recorded by Bourchardat and Tilden, in 1879 and 1882 respectively, that the hydrocarbon isoprene, C_5H_8, polymerises under certain conditions to form a rubber-like substance. Tilden in particular showed that the product thus obtained behaved exactly like natural rubber and could be vulcanised. These discoveries were the starting-point of the subsequent attempts to prepare synthetic rubber, and the early work in connection with the subject was devoted to

devising methods for (1) the production of isoprene cheaply, and (2) the conversion of the isoprene into rubber. Subsequently it was found that other hydrocarbons such as butadiene (C_4H_6) and diisopropenyl (C_6H_{10}), which contain two conjugated double linkages like isoprene, also polymerise in the same way with the production of rubber-like products, and butadiene and its derivatives have recently been adopted instead of isoprene in many processes for the production of synthetic rubber.

The rubbers obtained by the polymerisation of the two hydrocarbons isoprene and butadiene will not be identical, but they will be closely related (possibly homologues), and they appear to possess very similar physical properties. The butadiene rubber may, therefore, prove to be as suitable for technical purposes as the isoprene rubber, although differing somewhat from it in composition, but this point will require to be demonstrated by actual trials.

A very large number of patents have been taken out during the last few years for methods of preparing synthetic rubber, and it is quite impossible to deal with the subject in detail. The principal recent workers have been Professor C. Harries of Berlin, who has published a number of very valuable papers on the subject, the chemists of the Baeyer Farbenfabrik at Elberfeld, the Badische Anilin und Soda Fabrik, and Messrs. Schering in Germany, whilst in this country the group of chemists associated with the Synthetic Products Company, Ltd., have been prominent.

The credit of first producing synthetic rubber in quantity belongs to the Baeyer Farbenfabrik at Elberfeld, where sufficient of the product was obtained to make two complete sets of motor tyres as well as numerous manufactured articles. It was stated at the International Congress of Applied Chemistry held at New York in 1912 that one set of these tyres had run over 10,000 miles. The process used at Elberfeld for the preparation of synthetic rubber was worked out by Dr. F. Hofmann, and consists of the production of isoprene from *p*-cresol, a coal-tar distillation product, and the subsequent conversion of the isoprene into rubber by means of heat or by the addition of certain substances such as albumen, blood serum, starch, and glycerin. The

firm has recently patented a method in which a piece of the polymerised rubber is used to bring about the polymerisation of a further quantity of isoprene or butadiene.

The group of English chemists already referred to has worked out three possible processes for the preparation of isoprene or butadiene: (1) the production of isoprene from isoamyl alcohol, a process which will only be of value if a cheap method of manufacturing isoamyl alcohol is discovered; (2) the production of butadiene from butyl alcohol, the latter being stated to be obtainable at a price probably not exceeding £40 to £45 per ton by a new fermentation process discovered by Professor Fernbach; and (3) the conversion of ordinary alcohol into aldehyde, aldol, and finally butadiene. In addition Dr. Matthews discovered the important fact that metallic sodium brings about the polymerisation of isoprene and butadiene almost quantitatively at the ordinary temperature, a point which Harries also discovered independently.

The present position of synthetic rubber may be summed up as follows:

The production of rubber synthetically by chemical means has been successfully accomplished, but it is still doubtful whether synthetic rubber could be manufactured at a price which would enable it to compete with the natural product, especially in view of the gradual fall in the price of rubber which is likely to take place in the future as the result of the increasing production from the plantations. At the present time, therefore, it would appear that natural rubber is not likely to be displaced by the synthetic product, but it must always be borne in mind that the situation may be materially altered by the results of the chemical research work which is actively proceeding in many different quarters with a view to cheapening the cost of manufacturing the synthetic material.

Analysis of Crude Rubber.—In the analysis of crude rubber the following determinations are usually made:

(1) Loss on washing.
(2) Ash.
(3) Resin.
(4) Protein.
(5) Caoutchouc.

The determinations of the ash, resin, protein, and caoutchouc are usually done on the dry washed rubber.

(1) *Loss on Washing.*—The "loss on washing" includes (*a*) the moisture present in the crude rubber; (*b*) the solid impurities; and (*c*) any substances soluble in water.

A weighed quantity of the rubber is treated in a rubber-washing machine until any impurities present are removed and it is converted into thin crêpe. The crêpe rubber is dried, at first in the air and finally in a vacuous desiccator. The difference between the final weight of the dry rubber and the original weight is the "loss on washing."

The amount of moisture present in the original sample may be determined if desired (1) by heating a weighed quantity of the rubber *in vacuo* until it ceases to lose weight; or (2) by heating the rubber in a current of hydrogen or carbon dioxide and weighing the water given off.

(2) *Ash.*—A weighed quantity of the washed rubber is incinerated and the residue is heated in a muffle furnace until all the carbon disappears.

(3) *Resin.*—A weighed quantity of the washed crêpe rubber, cut into fine shreds, is thoroughly extracted with acetone in a Soxhlet apparatus. The acetone is then distilled off from a weighed flask, and the flask with the residue is dried in a vacuous desiccator until of constant weight. The portion soluble in acetone is returned as resin.

Glacial acetic acid is sometimes used as a solvent for the resin in place of acetone.

(4) *Protein.*—The amount of nitrogen is determined by Kjeldahl's method, and the result multiplied by 6·25 to represent protein. This assumes that all the nitrogenous substances present in rubber are protein, which, however, is improbable.

(5) *Caoutchouc.*—The percentage of caoutchouc in the dry washed rubber is usually obtained by difference—viz. 100 minus the sum of the percentages of ash, resin, and protein.

The determination of the caoutchouc by difference is not satisfactory, but at present there is no method of direct estimation which can be used successfully. Proposals have been made to determine the caoutchouc by

separating it as the tetrabromide or as nitrosite, and methods for these purposes have been devised by a number of chemists. It is, however, difficult to obtain concordant results with these methods, and they have in consequence been generally abandoned so far as the examination of raw rubber is concerned.

Another drawback to the present method of analysing crude rubber is that rubbers of very different quality often give similar figures on analysis. For example, it has been already pointed out that rubber from very young Para trees in Ceylon is apparently identical in composition with that from the older trees, the percentages of resin and caoutchouc being practically the same in each case. The rubber from the young trees is, however, usually much weaker than that from the older trees, and it would seem that this difference in strength must be due to some difference in the caoutchouc, which is not revealed by the present methods of analysis. Until some progress can be made in this direction it will not be possible to correlate the results of the chemical analysis with the physical properties of the rubber.

Viscosity of Rubber Solutions.—It is well known that as a general rule the best qualities of rubber furnish the most viscous solutions, and it was suggested by Axelrod * and subsequently by Schidrowitz and Goldsbrough † that the viscosities of the solutions might be used to measure the strength or "nerve" of the crude rubbers. For the purpose of the determinations Schidrowitz and Goldsbrough recommend dilute solutions of rubber (0·25 to 1·5 per cent.) in thiophene-free benzene, and they determine the viscosities in an Ostwald viscosimeter at a temperature of 20° C. The comparative viscosities are measured by the rate of flow of the solutions compared with that of benzene in the same apparatus. At least three determinations are made with solutions containing approximately 0·25, 0·5, and 1·0 per cent. of rubber, and the results are plotted as a curve. Schidrowitz has proposed to express the viscosity by a number obtained by drawing a tangent to the curve at a concentration of 1 per cent. and taking the value of this tangent on a standard scale.

* *Gummi Zeitung*, 1905, vol. xix. p. 1053; vol. xx. p. 105.

† *Journal of Society of Chemical Industry*, 1909, p. 3; and *Rubber*, by P. Schidrowitz (London: Methuen & Co., Ld.).

A considerable amount of work on these lines has been conducted by several investigators,* but although interesting results have been obtained, it has been found that the classification of crude rubbers according to the viscosities of their solutions does not always agree with that based on the tensile tests of the vulcanised rubbers. Schidrowitz considers that so far as the rubber of one particular species is concerned, the order of the viscosity figures can be accepted as an indication of the relative strengths of different specimens, but he admits that this conclusion does not hold good for rubbers derived from different species. It therefore appears doubtful at present whether the viscosity method will prove to be of general application, although it may be useful in dealing with any one variety of rubber.

It has been found by Schidrowitz that the viscosity of rubber solutions is affected by the temperature at which the determination is made; that the effect of heating the solution is sometimes to increase and sometimes to diminish the viscosity; that the removal of the resin from rubber usually increases the viscosity; and that with rubber from the same species the method of coagulation has considerable influence on the viscosity.

Mechanical Testing of Rubber.—In view of the fact that the technical value of rubber depends on the physical properties of the vulcanised product, considerable attention has been devoted recently to the mechanical testing of vulcanised rubber as a means of accurately determining the comparative qualities of different specimens. The suggestion has been made that the crude rubbers might be submitted to mechanical tests, but it would be exceedingly difficult in most cases to obtain suitable homogeneous test pieces, and, moreover, it would have to be shown that the results thus obtained from the crude rubbers held good for the vulcanised products. The plan of making the tests on the vulcanised rubber has therefore been generally adopted.

The tests usually made involve the determination of (1) the tensile strength; (2) the resistance to compression; (3) the resistance to abrasion; (4) the hardness; and (5) the resiliency.

* See paper by J. G. Fol in *The India-rubber Journal*, March 22, 29, April 5, 12, 1913.

Only a brief notice of this important subject is possible here, and for further details reference should be made to the literature on the subject.*

Tensile Tests.—A number of machines have been devised for determining the tensile properties of rubber, one of the best known of which is the Schopper machine. Another useful machine is that of Schwartz, which is specially designed for making hysteresis tests on strip rubber.

The tensile tests include the determination of the breaking-strain and the elongation at the breaking-point; the elongation with intermediate loads; the elongations with fixed load; the loads required for fixed elongation; the amount of subpermanent set either after elongation to a constant limit or under a fixed load; the behaviour on repeated elongations, etc.

A most important point in connection with these tests is the form of the test piece. Experiments made by Memmler have shown that the rod form of test piece with thickened ends is not satisfactory in many cases, especially with rubbers exhibiting good elasticity; if gripped sufficiently tightly to prevent slipping it frequently breaks near one of the jaws. The ring form is much better; but stationary rings do not give constant results, and the best method appears to be that adopted in the Schopper machine—viz. a ring of standard dimensions which is evenly rotated during the application of tension.

Compression Tests.—These tests can be made by an ordinary testing machine, or by means of a special machine designed by Professor Martens in which cylindrical pieces of rubber, from the same or different mixings, can be subjected to varying pressures and the extent of the compressions read off on a scale. The effect of repeated compressions is usually also determined.

Abrasion Tests.—These are usually made by holding the specimens against a revolving emery or carborundum wheel by means of a constant weight or pressure, or by making balls or rings of the rubber to revolve between metallic discs or rollers which are pressed together by a constant weight. The loss of weight after a fixed number

* See *Der Kautschuk und seine Prüfung* by Hinrichsen and Memmler (S. Hirzel, Leipzig).

of revolutions at constant load indicates the difference in the resistance to abrasion of the different pieces.

Hardness Tests.—The hardness is measured by the indentation produced by a steel ball pressed on to a disc of the rubber by a constant weight ; or by the load required to produce a given indentation.

Resilience.—This is measured by the height of rebound of a steel ball after dropping from a fixed height on to a disc of the rubber, or by means of a pendulum-impact tester, one arm of which carries a piece of the rubber to be tested.

There is no doubt that the mechanical testing of rubber on these lines will furnish very important data, not only for the manufacturer but also for the planter, by indicating the methods of preparation which produce the highest quality of rubber.

CHAPTER VIII

STATISTICS OF CONSUMPTION AND PRICES

PARTICULARS of the production of rubber in the principal countries of origin have been given in Chapter I., and in concluding this general section of the book it is proposed to give some statistics regarding the consumption of rubber in the principal manufacturing countries, and the market values of the different grades of rubber.

Countries of Consumption.—The principal countries which use rubber for manufacturing purposes are the United Kingdom, the United States, Germany, and France.

The imports of rubber into the United Kingdom have steadily increased from 23,324 tons in 1901 to no less than 45,298 tons (out of an estimated world's production of 85,000 tons) in 1911, and 55,024 tons (out of an estimated world's supply of 96,000 tons) in 1912. A considerable part of this rubber is re-exported to other countries, but the amount retained for home consumption has increased from 8,634 tons in 1901 to 20,454 tons in 1910, 16,736 tons in 1911, and 18,726 tons in 1912. The following table shows (1) the total imports of rubber into the United Kingdom, (2) the exports, and (3) the amount retained for home consumption, for each year since 1901 :

UNITED KINGDOM

IMPORTS AND EXPORTS OF RAW RUBBER

	Total imports.	Exports.	Retained for home consumption.
	Tons.	Tons.	Tons.
1901 . . .	23,324	14,690	8,634
1902 . . .	20,969	14,588	6,381
1903 . . .	24,305	16,812	7,493
1904 . . .	24,802	14,918	9,884
1905 . . .	29,672	16,725	12,947
1906 . . .	30,350	16,513	13,837
1907 . . .	33,365	17,451	15,914
1908 . . .	28,753	17,926	10,827
1909 . . .	35,003	19,896	15,107
1910 . . .	43,848	23,394	20,454
1911 . . .	45,298	28,562	16,736
1912 . . .	55,024	36,298	18,726

The corresponding figures for the United States, Germany, and France since 1906 are given in the following tables. The figures for France, it may be noted, include both rubber and gutta percha.

UNITED STATES

Imports and Exports of Raw Rubber

Year (to June 30).	Total imports.	Exports.	Retained for home consumption.
	Tons.	Tons.	Tons.
1906 . . .	25,823	1,710	24,113
1907 . . .	34,359	1,882	32,477
1908 . . .	27,783	1,835	25,948
1909 . . .	39,446	1,693	37,753
1910 . . .	45,109	2,899	42,210
1911 . . .	40,980	2,504	38,476
1912 . . .	55,557	2,593	52,964

GERMANY

Imports and Exports of Rubber (Raw and Purified)

	Total imports.	Exports.	Retained for home consumption.
	Metric tons.	Metric tons.	Metric tons.
1907 . . .	15,808	4,763	11,045
1908 . . .	14,741	4,370	10,371
1909 . . .	15,550	4,066	11,484
1910 . . .	18,705	4,930	13,775
1911 . . .	19,948	4,667	15,281
1912 . . .	20,586	4,943	15,643

FRANCE

Imports and Exports of Raw Rubber and Gutta Percha

	Total imports.	Exports.	Retained for home consumption.
	Metric tons.	Metric tons.	Metric tons.
1906 . . .	12,373	7,849	4,524
1907 . . .	12,678	7,527	5,151
1908 . . .	10,919	6,798	4,121
1909 . . .	13,393	9,071	4,322
1910 . . .	17,302	13,503	3,799
1911 . . .	18,106	12,708	5,398

It will be seen from these figures that a very large proportion of the raw rubber produced annually is utilised for manufacturing purposes by the three countries the United States, the United Kingdom, and Germany. During the four years, 1909 to 1912, the United States took about half the world's estimated supply of raw rubber, whilst the share of the United Kingdom was from one-fourth to one-fifth of the total, and that of Germany slightly less.

Rubber Markets.—The principal markets for raw rubber are London and Liverpool in the United Kingdom, New York in the United States, Hamburg in Germany, Antwerp in Belgium, Havre and Bordeaux in France, and Lisbon in Portugal. The following table shows the imports of rubber at these different ports irrespective of its destination:

	1906.	1907.	1908.	1909.	1910.	1911.
United Kingdom:						
Liverpool, tons . .	22,461	23,526	22,329	24,364	28,647	24,977
London, tons . .	4,563	4,617	4,107	6,898	11,199	16,011
United States:						
New York, tons . .	24,337	32,156	25,722	36,375	39,874	36,914
Germany:						
Hamburg, metric tons	16,455	16,803	14,116	15,561	19,089	19,873
Belgium:						
Antwerp,* metric tons	5,772	5,054	5,035	4,686	4,059	4,336
France:						
Havre, metric tons	4,392	4,464	3,498	3,781	4,458	4,008
Bordeaux, metric tons	1,716	1,516	1,078	1,988	2,326	1,833
Portugal:						
Lisbon, metric tons	2,334	2,628	2,441	3,036	3,424	2,739

The four principal markets for raw rubber are, therefore, New York, Liverpool, Hamburg, and London. The rapid rise in the amount of rubber received at London during the last four years is due to the largely increased production of plantation Para rubber in Malaya and Ceylon, which is chiefly marketed in London.

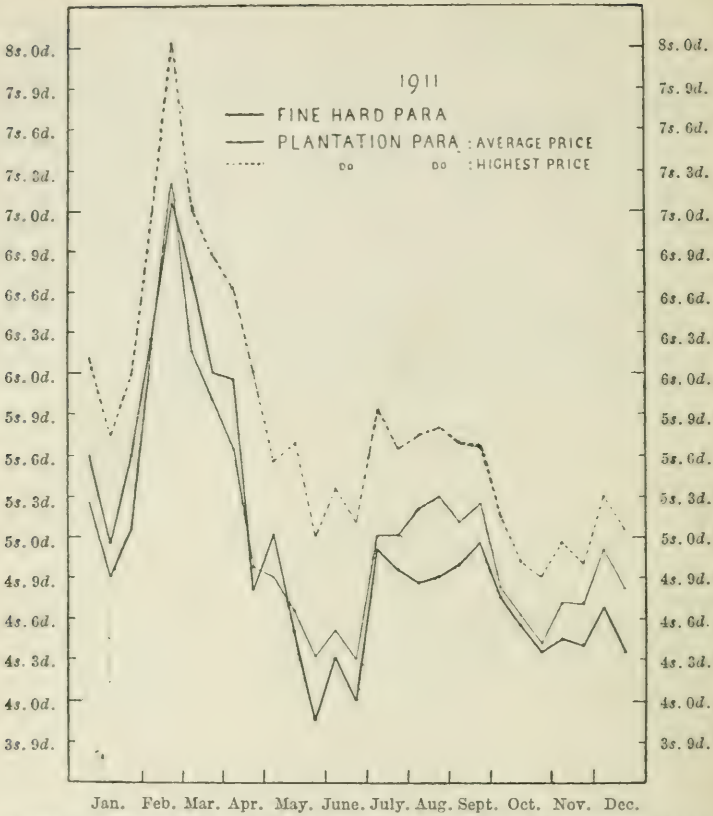
* Rubber in transit not included.

Market Values.—Fine hard Para rubber from South America forms the market standard of value, and during the last few years its price has fluctuated very widely. From 1906 to 1908 the selling-price of fine hard Para in London varied from 2*s*. 9*d*. to 5*s*. 5*d*. per lb., but during 1909 and 1910, the years of the rubber boom, the price rose considerably, and a record of 12*s*. 6*d*. per lb. was reached in April 1910. Since the latter date, however, the price has gradually fallen to a normal level. The fluctuations in the value of fine hard Para in London since 1906 are shown in the following table, which gives the highest and lowest quotations during each year, together with similar figures for plantation Para :

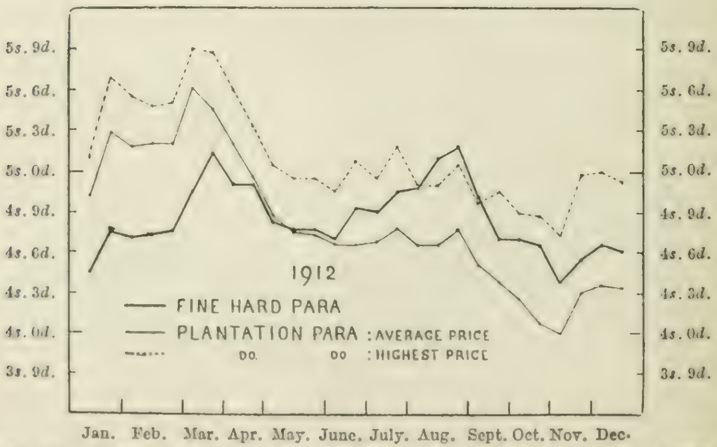
Year.	Fine hard Para.		Fine plantation Para.	
	Highest.	Lowest.	Highest.	Lowest.
	s. d.	*s. d.*	*s. d.*	*s. d.*
1906 . . .	5 5	5 0	6 3	5 5
1907 . . .	5 2	3 3¾	5 10	3 8
1908 . . .	5 5	2 9	6 0	3 2
1909 . . .	9 3½	5 0½	9 8½	5 1½
1910 . . .	12 6	5 7	12 10	5 2¼
1911 . . .	7 2½	3 10½	8 0¼	4 6
1912 . . .	5 2	4 3½	5 8½	4 1

It will be seen from these figures that during the above years fine plantation Para usually realised a slightly higher price than fine hard Para. It must, however, be remembered in this connection that plantation Para is placed upon the market in an almost dry condition (containing only 1 or 2 per cent. of moisture), whereas fine hard Para contains from 10 to 20 per cent. of moisture. If this fact is taken into consideration it will be found that the price of dry fine hard Para was a little above that of dry plantation Para.

The following diagrams, based on the figures given in Messrs. Gow, Wilson & Stanton's reports of the London rubber auctions, show the fluctuations during 1911 and 1912 in the values of fine hard Para and plantation Para.



PRICES OF FINE HARD PARA AND PLANTATION PARA DURING 1911.



PRICES OF FINE HARD PARA AND PLANTATION PARA DURING 1912.

During the first six months of 1913 the price of plantation Para gradually fell in comparison with that of fine hard Para, and during June and July the latter rubber was quoted as much as 1*s.* per lb. above first grade plantation Para. The course of the market is shown by the following comparison of prices at different dates :

1913.	Fine hard Para.	Plantation Para. Highest.	Plantation Para. Average.
	s. *d.*	*s.* *d.*	*s.* *d.*
January 16	4 $6\frac{3}{4}$	4 $9\frac{3}{4}$	4 $5\frac{1}{8}$
February 13	4 $2\frac{3}{4}$	4 $5\frac{1}{4}$	4 $1\frac{1}{2}$
March 13	3 $11\frac{1}{4}$	4 3	3 $10\frac{5}{8}$
April 18	3 $4\frac{3}{4}$	3 $8\frac{3}{4}$	3 $1\frac{1}{4}$
May 22	3 10	3 $5\frac{1}{4}$	3 $2\frac{1}{2}$
June 19	3 $8\frac{1}{2}$	3 $1\frac{3}{4}$	2 $8\frac{3}{4}$
July 17	3 10	3 $0\frac{1}{4}$	2 $7\frac{3}{8}$

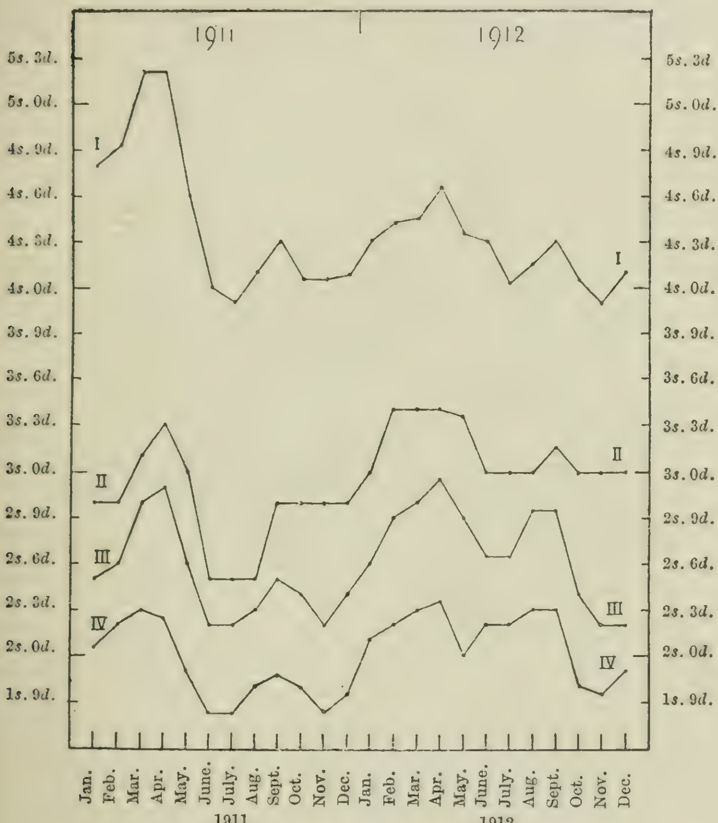
The African rubbers prepared by the natives are mostly of second quality and realise lower prices than fine hard Para. The demand for these grades of rubber is, however, usually very good, and their value is frequently higher in comparison with that of fine hard Para than is warranted by their composition. The best of the native African rubbers are the "niggers"—*i.e.* the Landolphia rubbers prepared in the form of balls—and the highest grades of this type always realise good prices. The values at Liverpool of some typical grades of West African rubber are given in the following list, taken from the market report of Messrs. Taylor & Co. Fine hard Para was quoted on the same date at 3*s.* 10*d.* per lb., and fine plantation Para at 2*s.* 11*d.* per lb.

	Price per lb. (July 1, 1913).			
	s. *d.*		*s.* *d.*	
Gambia :				
Fair A.	1 $11\frac{1}{2}$	to	2 0	
2nds A.M. and C. . .	1 5	,,	1 9	
Sierra Leone :				
Twists, fair to prime black .	1 8	,,	2 5	
Rooty Manoh . . .	1 5	,,	1 7	

	Price per lb. (July 1, 1913). s. d.			s. d.	
Gold Coast:					
Lump, hard selected	1	4		—	
,, soft	1	$3\frac{1}{4}$	to	1	$3\frac{1}{2}$
Niggers, fair red	2	7	,,	2	8
,, soaked white	1	9	,,	1	10
Flake or Paste	0	10		—	
Lagos and Benin:					
Lump	1	$6\frac{1}{2}$	,,	1	9
Niggers, Lagos	1	9	,,	2	0
Calabar:					
Niggers	2	0	,,	2	1
Ball	2	0	,,	2	1
Lump	1	7	,,	1	8
Roots	1	3	,,	1	5
Conakry:					
Rio Nunez Niggers, fair average quality to good	2	9	,,	2	10
Niggers, fair average quality	2	$5\frac{1}{2}$	,,	2	6
,, white	2	3	,,	2	$4\frac{1}{2}$
Biscuits and sheets, fair to good	2	7	,,	2	8
Ivory Coast:					
Lump, hard selected	1	4		—	
Niggers, fair red	2	$9\frac{1}{2}$	,,	2	10
,, ,, white	2	2	,,	2	$2\frac{1}{2}$
,, ,, pinky	1	9	,,	1	10
Gaboon:					
Large ball	2	0	,,	2	1
Small ball	1	11	,,	2	0
Benguela:					
Niggers, prime	2	8	,,	2	9
,, fair average quality	2	1	,,	2	2
Niger balata, fair	1	7	,,	1	8
,, gutta	0	$7\frac{1}{2}$	,,	0	8
,, flake	0	10		—	

The diagram on p. 99 shows the fluctuations during the years 1911 and 1912 in the values of best and second-quality "niggers," represented by Gold Coast red niggers and Lagos niggers respectively, and of lump rubber from Southern Nigeria and the Gold Coast.

It will be seen from the preceding quotations that the rubber of *Funtumia elastica* as prepared in the form of "lump" by the natives is only of low value, realising less than half the price of fine hard Para. If, however, the



PRICES OF AFRICAN RUBBERS.

I. Gold Coast Red Niggers. III. Lagos and Benin Lump.
II. Lagos Niggers. IV. Gold Coast Lump.

rubber is carefully prepared in biscuits, sheet, or crêpe from the unadulterated latex of *Funtumia elastica*, it is of very good quality and of much higher value. Thus, for example, a large consignment of Funtumia rubber in biscuit form, obtained by tapping the communal plan-

tations of these trees in Southern Nigeria, was divided into three grades which were sold in London at 6*s*. 6*d*., 6*s*. 1½*d*., and 5*s*. 6*d*. per lb. with fine plantation Para at 6*s*. 11*d*. per lb. Similarly Funtumia rubber prepared in the form of sheet or crêpe in Uganda has realised prices above that of fine hard Para.

CHAPTER IX

THE PARA RUBBER TREE
HEVEA BRASILIENSIS, MÜLL. ARG.

Species of Hevea.—The trees belonging to the genus Hevea are natives of South America, and up to the present time about twenty species have been described. The most important rubber-yielding species is *Hevea brasiliensis*, Müll. Arg., the well-known Para rubber tree, which is widely distributed in the Amazon valley and furnishes the best rubber of commerce. In addition to this tree, however, a number of the other species of Hevea also yield marketable rubber, and a short notice of these may be given before dealing in detail with the Para tree.

Dr. J. Huber, the Director of the Museu Goeldi at Para, has made a special study of the Heveas, and he divides the Brazilian species into three groups according to the quality of the rubber which they furnish. The first group, yielding rubber of the highest quality, is composed of *H. brasiliensis*, Müll. Arg., *H. Benthamiana*, Müll. Arg., and the closely related species, *H. Duckei*, Hub. *H. brasiliensis* is confined to the southern basin of the Amazon, whereas the other two species are found to the north of the main stream, *H. Benthamiana* being common on the Rio Negro and *H. Duckei* on the Yapura river. The smoked rubber of the two latter species is stated to be nearly equal to that of *H. brasiliensis*.

The second group of Hevea consists of *H. guianensis*, Aubl., *H. collina*, Hub., *H. nigra*, Ule, *H. cuneata*, Hub., *H. lutea*, Müll. Arg., and *H. paludosa*, Ule. All these species are stated to yield a second-quality rubber which is smoked in the same way as that of *H. brasiliensis*, and is known in Brazil as "borracha fraca" or weak rubber. These trees do not usually grow in the same districts as *H. brasiliensis*, and consequently their latices are not

added to that of the latter species; they are generally very scattered in the forests and are only rarely exploited by the natives.

The third group comprises *H. Spruceana*, Müll. Arg., *H. discolor*, Müll. Arg., *H. similis*, Hemsl., and *H. viridis*, Hub. These trees give only a small quantity of latex which furnishes a weak, sticky rubber, and they are therefore of little practical importance.

Good rubber is said to be obtained from several other species of Hevea, such as *H. rigidifolia*, Müll. Arg., *H. minor*, Hemsl., and *H. microphylla*, Ule, which occur on the Rio Negro, but according to Huber there is at present little authentic information available regarding the value of these trees. The *Hevea confusa*, Hemsl., of British Guiana also furnishes marketable rubber, but the yield is small (see *Bulletin of the Imperial Institute*, vol. x. 1912, p. 388).

Botanical Characters.—*Hevea brasiliensis* is a large forest tree which may attain a height of 100 ft. It has a well-developed trunk, sometimes measuring 10 to 12 ft. in circumference, and the branches are high. The leaves have a long petiole and are trifid, the three leaflets being lanceolate with acuminate apex. The flowers, which are small, green, and sweetly scented, are unisexual and are borne in panicles which contain both male and female flowers. The fruit is a three-celled triangular capsule, each division of which contains a single oval seed having a shiny brown mottled seed-coat. When ripe the capsule bursts and scatters the seeds to a considerable distance. (See Plate II.)

Hevea brasiliensis sheds its leaves every year, but only remains leafless for a short period. This change takes place both in its native habitat and also in the countries into which it has been introduced. According to Ule, the Para trees growing on the lower Amazon lose their leaves between March and July, flower in July and August, and ripen their fruits in January and February. In Ceylon the Para trees usually shed their leaves between January and March, and fruit from August to November, although in the Uva Province the fruiting period is from February to April. The fall of the leaves occurs in Malaya between January and March as in Ceylon, but the trees ripen their fruits either in the early part of the year, the maximum crop being then in March, or from July to October.

Hevea brasiliensis, Müll. Arg., the Para Rubber Tree

A. Flowering shoot B. Leaf C. Seeds

The kernels of Para rubber seed have been shown by examination at the Imperial Institute to contain about 45 per cent. of a drying oil which can be used for the same purposes as linseed oil (see Imperial Institute *Selected Reports on Rubber and Gutta Percha*, pp. 434–40).

Distribution.—*Hevea brasiliensis* is very widely distributed throughout the entire valley of the Amazon to the south of the main stream, its habitat comprising portions of Brazil, Bolivia, and Peru. It occurs on the low islands and shores of the Amazon estuary, and on the alluvial lands bordering the main stream and all its southern tributaries. At the mouth of the Amazon the trees grow above the limits of the tidal floods, but on the alluvial lands of the lower rivers they are subject to annual inundations during the wet season. *Hevea brasiliensis* also occurs in certain districts on the higher lands between the rivers, and it was from such trees growing between the Tapajoz and Madeira rivers that Wickham in 1876 collected the seeds which served to introduce the Para tree into Ceylon and the Straits Settlements. Some doubt has been expressed, however, as to whether the Hevea trees growing on the higher lands are always the true *H. brasiliensis*, and Ule is of opinion that the tree which occurs in such situations in the Acre district is a distinct species.

According to Huber, the principal districts in the Amazon valley where *Hevea brasiliensis* is abundant are the forests situated on the shores and islands of the estuary and along the banks of the rivers in the State of Para ; the valleys of the Xingu, Tapajoz, and Madeira rivers (the latter partly in Brazil and partly in Bolivia) ; the Acre territory ; and the valleys of the rivers Purus, Jurua, and Jutahy in Brazil, the Javary forming the boundary between Brazil and Peru, and the Ucayali in Peru. Brazil possesses large reserves of Para trees which have not yet been exploited owing to difficulties of transport, but several of these areas are now being opened up.

Climatic Conditions in Brazil.—The characteristic features of the climate of the Amazon valley are a uniform temperature and a considerable rainfall well distributed throughout the year. On the lower river the mean annual temperature lies between 76° and 81° F. and the annual rainfall is usually from 80 to 120 in. In this region the principal rainy season lasts from October to March,

and July, August, and September are the driest months. The climatic conditions on the upper tributaries and on the higher lands no doubt differ in some respects from those of the lower river.

Collection and Preparation of Para Rubber in Brazil.— The rubber is usually collected during the dry season, the occurrence and duration of which vary considerably in the different districts. As a rule, the tapping is conducted between May and February, and the best period is stated to be from May to September.

The native collector first selects from 100 to 150 Hevea trees growing in close proximity in the forest, and, in order to facilitate his subsequent operations, he connects these by a path beginning and ending at his hut. Such a group of trees is known as an "estrada." The general method of working an estrada is as follows: The collector, starting at or before sunrise, taps each tree in turn by the method described below, and, having completed the round, he is back at his hut. After a short interval he again sets out to collect the latex, which he carries to his hut and converts into rubber the same day.

The tapping is performed with a small axe having a cutting edge only 1 to 1½ in. long. With this instrument the collector makes one or more incisions in the bark and immediately fixes a tin cup beneath the cut to catch the latex. The incisions, which are made in a slanting direction, are usually placed horizontally one or two feet apart round the trunk, so that the number of incisions made on a tree at each tapping depends upon its circumference. Sometimes the collectors make the first incisions at the base of the tree and work upwards, whilst in other cases they commence operations at a height of 6 ft. or more and make the succeeding incisions below. The second day's incisions are made about 4 in. vertically above or below the first, and the series is continued in this way until the row is completed. A new series of cuts is then commenced at the side of the first row.

In some districts of Brazil the trees are tapped every day, whereas in others the tapping is only performed every other day. In the latter case it is usual for the collector to work two estradas alternately so as to obtain a daily yield. Tapping is usually suspended during rain. It is estimated that the number of tappings received by

the trees during the collecting season varies from 90 to 120 according to the district. It is generally stated that only a very small yield of rubber is obtained from the initial tappings as the latex is at first thick and does not flow freely, but that after several tappings have been made the latex becomes more fluid and the yield of rubber considerably increased.

The coagulation of the latex is effected in the following manner: The collector makes a small fire over which he places a conical iron or earthen chimney which serves to direct the smoke upwards. The fire is fed from time to time with the shells of certain palm nuts which in burning give off dense clouds of smoke containing creosote compounds. The nuts commonly used for this purpose are the Urucury (*Attalea excelsa*) and the Inaja (*Maximilliana regia*). He then takes a round pole of wood about 6 ft. long, which he supports at one or both ends so that the middle portion can be held in the smoke. A small quantity of latex is poured on to the centre of the pole which is immediately turned round and round in the smoke until the latex is completely coagulated, forming a thin film of rubber. This procedure is repeated until the whole of the latex obtained in the day's tapping is coagulated and it is continued day by day until a sufficiently large ball of rubber is formed, which is then removed from the pole. These balls of rubber usually weigh from 20 to 60 kilograms (44 to 132 lb.), and, when cut, they are seen to be built up of a number of well-marked concentric layers of rubber each of which represents a day's yield.

If the smoking has been carefully done so that each layer of latex is completely coagulated, the rubber is classed as "fine"; if, however, the coagulation is not complete throughout the ball, the rubber is known as "entrefine." A third class of rubber, known as "sernamby," consists of the scrap rubber from the incisions, collecting-cups, etc.

The amount of rubber obtained from the wild Para trees of the Amazon valley appears to vary considerably in the different districts. According to figures published by various observers, the average annual yield of freshly coagulated rubber ranges from about 2 lb. to as much as 8 or 10 lb. per tree. The higher yields are obtained in

districts which have been opened comparatively recently and where many of the trees are being tapped for the first time. In the Lower Amazon region, where the forests have been worked for many years, the average yield appears to be between 2 and 3 lb. per annum.

Cultivation of Hevea brasiliensis.—The introduction of the Para rubber tree into tropical countries outside South America was successfully accomplished in 1876 as the result of the labours of Wickham, who collected seeds of the plant in Brazil. This mission was undertaken at the instance of the Government of India in co-operation with the Royal Botanic Gardens, Kew, and the plants raised at Kew were distributed to India, Ceylon, Singapore, and other countries. The plants sent to Ceylon and Singapore were found to grow well under the local conditions, and it is from these parent trees that the extensive plantations now existing in Ceylon and Malaya have been formed.

Hevea brasiliensis not only furnishes rubber of the highest quality, but it also gives a larger annual yield than any other rubber tree. On these grounds its cultivation is to be recommended in preference to that of any other rubber tree wherever it is likely to thrive, and it will therefore be of interest to consider the climatic and other conditions under which the tree has been successfully grown.

Climatic Conditions.—The conditions which prevail on the Lower Amazon have been already described, and it was at first thought that similar conditions would be necessary for the cultivation of the tree. It has been found, however, that the Para rubber tree possesses very considerable powers of adaptation, and it is at present being grown successfully under very varied conditions of temperature, rainfall, and elevation.

In Ceylon the Para tree has been widely cultivated and has been found to grow particularly well in the following districts: Kelani Valley, Kalutara, Ratnapura, Matale, Kegale, Galle, Kandy, Kurunegalle, and Badulla. The best results have been obtained in the low moist country; but the tree is being successfully grown up to 2,000 ft. in the Central Province and up to 3,000 ft. in the Uva Province. The mean annual temperature of the low districts such as Galle and Ratnapura is about 80° F., whilst at Badulla, which is situated at an altitude of 2,225 ft., it is 73·4° F. In the rubber districts rain falls every

month throughout the year, the monthly variation being from 5 to 24 in., and the annual rainfall ranges from 75 to 160 in. Under the conditions prevailing in the island the minimum rainfall for the successful cultivation of the tree is regarded as about 70 in. per annum.

The climate of the Federated Malay States has proved to be exceedingly suitable for the cultivation of the Para tree. This country has a hot moist climate and a very uniform temperature. The general rainfall is about 90 to 100 in. per annum, and is distributed throughout the year; the driest month, July, seldom has less than 3½ in. of rain. The average maximum and minimum temperatures in the low country are 90° and 70° F. respectively, with a mean of about 80° F. Para trees are growing in the Federated Malay States at elevations up to 2,500 ft., but the best results are obtained from sea-level up to 300 ft.

In Southern India the climatic conditions are on the whole very different from those of Ceylon. It is much hotter at similar elevations, and except in certain districts there are at least three months of dry weather or with a rainfall of less than 1 in. per month. Where the rainfall is sufficient, the Para tree can be grown at higher altitudes than in Ceylon, and satisfactory results are being obtained on estates situated up to 3,500 ft. above sea-level.

On the West Coast of Africa the Para tree has been successfully grown at Aburi in the Gold Coast at an elevation of 1,500 ft. with an average annual rainfall of 47 in. and an average mean temperature of about 81° F. The tree, however, does much better at Tarquah in the same Colony, where the altitude is about 300 ft. and the average rainfall about 70 in. per annum.

In Southern Nigeria the Para tree is being cultivated with very satisfactory results in the wet zone of the Colony lying to the south of 6° 15′ N. latitude. At eight places within this area the rainfall ranges from 87·08 to 251·49 in. per annum, with an average of 128·67 in., whilst the maximum temperature during December to March is 88° F. and the minimum during May to August is 73° F.

In Uganda, Para trees have grown well at Entebbe, which is situated at an elevation of 3,863 ft., and has an average rainfall of about 58 in. and maximum and minimum temperatures of 86·5° F. and 55° F. respectively. The climate of the East Africa Protectorate is not very

suitable for the Para tree, and in Nyasaland it can only be grown in the West Nyasa district.

Soils.—In the first attempts to cultivate the Para tree, land was selected so as to approximate as nearly as possible to the conditions which prevail on the Lower Amazon. Low-lying alluvial land on the banks of rivers, and in some cases subject to periodical inundations, was consequently chosen for the purpose. As the result of planting experiments, however, it was found that land of this type was not essential for the successful growth of the tree, and it is now recognised that the character of the soil is of less importance than the rainfall and temperature. If the climatic conditions are satisfactory the Para tree will thrive on relatively poor soils. Wherever possible, however, it should be planted on good alluvial soil, as it then makes the quickest growth. The tree will not grow on swampy soil, but such land can be rendered suitable for its cultivation by thorough drainage.

The character of the soils upon which the Para tree is being successfully grown in Ceylon and the Federated Malay States will be seen from the following summary of analyses :

CEYLON SOILS *

	Kelani.	Kalutara.	Ratnapura.	Matale.
	Per cent.	Per cent.	Per cent.	Per cent.
Mechanical analysis :				
Fine soil passing 90 mesh .	14 to 35	11 to 28	17 to 20	15 to 30
Fine soil passing 60 mesh .	20 ,, 40	16 ,, 40	16 ,, 25	14 ,, 25
Medium soil passing 30 mesh .	3 ,, 8	4 ,, 10	4 ,, 5	3 ,, 7
Coarse sand and small stones .	30 ,, 60	30 ,, 70	50 ,, 60	40 ,, 60
Moisture . .	2 ,, 6	2 ,, 6	3 ,, 5	3 ,, 6
Chemical composition :				
Organic matter	8 ,, 13	7 ,, 15	10 ,, 12	8 ,,14
Nitrogen . .	0·05 ,, 0·2	0·1 ,, 0·15	0·1 ,, 0·2	0·1 ,, 0·2
Lime . .	0·05 ,, 0·15	0·03 ,, 0·15	0·06 ,, 0·2	0·08 ,, 0·2
Magnesia . .	0·05 ,, 0·35	0·04 ,, 0·2	0·07 ,, 0·15	0·05 ,, 0·25
Potash . .	0·05 ,, 0·2	0·04 ,, 0·2	0·04 ,, 0·1	0·03 ,, 0·25
Phosphoric acid	traces to 0·07	traces to 0·06	0·03 ,, 0·8	0·01 ,, 0·1

* *Circulars and Agricultural Journal of the Royal Botanic Gardens, Ceylon*, Vol. III (1905), No. 6.

MALAY SOILS *

	Alluvial Clays.	Sandy loams.
	Per cent.	Per cent.
Mechanical analysis :		
Fine soil passing 90 mesh .	68 to 96	16 to 48
Fine soil passing 60 mesh .	4 ,, 32	24 ,, 38
Medium soil passing 30 mesh	—	8 ,, 28
Coarse sand and small stones .	—	4 ,, 32
Chemical Composition :		
Moisture	5·00 to 6·92	1·40 ,, 4·20
Humus and combined water	8·00 ,, 24·08	3·00 ,, 9·60
Oxides of iron and manganese	1·12 ,, 3·00	0·30 ,, 8·24
Alumina	2·52 ,, 3·02	1·16 ,, 5·69
Lime	0·16 ,, 0·28	0·14 ,, 0·24
Magnesia	0·23 ,, 0·38	0·086 ,, 0·144
Potash	0·014 ,, 0·169	0·014 ,, 0·053
Phosphoric acid . . .	0·012 ,, 0·076	0·051 ,, 0·076
Sand and silicates . .	64·20 ,, 81·00	73·60 ,, 93·80
Nitrogen	0·403 ,, 0·667	0·369 ,, 0·492

Formation of Plantations.—The first step in the formation of a rubber plantation is to clear the land by cutting down the existing trees, and then if the timber cannot be disposed of it is burnt when dry. It is desirable, if possible, to remove the stumps of the trees from the soil, as if these are allowed to remain they decay and serve to harbour white ants and fungoid diseases which may subsequently attack the rubber trees. The cost of removing the stumps is, however, considerable, but the work has been carried out on several estates with very satisfactory results. A number of mechanical appliances for facilitating the removal of the stumps are now available.

After the land has been cleared, suitable roads are made through the estate and any necessary drainage is done. The land is then divided into blocks and "holed" for the reception of the rubber plants. It is advisable to make the holes as large as convenient, since this is beneficial to the subsequent growth of the plant, and 2 ft. square by 1½ ft. deep is considered to be a good size. The holes should be refilled with surface soil a little time before planting out is commenced so that the soil may settle before the plants are placed in position.

Considerable discussion has taken place regarding

* Analyses by Bamber quoted in *Report of Director of Agriculture in the Federated Malay States for* 1906.

the distances at which Hevea trees should be planted, and there is still much divergence of opinion amongst planters on this point. At first close planting was generally adopted with the object of producing tall straight stems suitable for tapping, and the trees on many estates were planted 10 ft. by 10 ft. (over 400 to the acre). In these cases the intention was to thin out the trees subsequently, but this has not always been done. More recently there has been a growing opinion that much wider planting than the above is desirable, and the distance of the trees apart has been gradually increased. In Ceylon distances of 15 ft. by 20 ft. (about 150 trees to the acre) or 20 ft. by 20 ft. (about 110 trees to the acre) are now generally adopted, whilst in Malaya the usual arrangement is 20 ft. by 20 ft. or 24 ft. by 12 ft. (about 110 and 150 trees to the acre respectively). Some authorities recommend still wider planting, being of opinion that ultimately better results will be obtained from 40 or 50 trees per acre than from 100 to 200 trees on the same area.

Experiments conducted in Malaya and in Ceylon have shown that widely planted trees increase in girth much more rapidly than closely planted trees and that consequently the former will more quickly attain the necessary size for tapping.

Raising of Plants.—*Hevea brasiliensis* is usually propagated from seed, of which the trees produce large quantities after the fourth or fifth year. Seed intended for planting purposes should be preferably selected from vigorous trees eight to ten years old giving a large yield of rubber.

The plants are generally raised in nursery beds or in seed-baskets, but in some cases the seeds have been planted "at stake" in the position which the trees are to occupy.

When the plants are to be raised in nurseries, well-prepared beds of rich soil should be formed in a suitable position, and arrangements made for providing the young plants with shade. This is usually accomplished by means of a light framework about 8 ft. high upon which a covering of leaves or matting can be spread. The seeds are sometimes germinated in a seed bed and then transferred to the nursery bed, or they are at once planted in the nursery bed 6 to 9 in. apart and 1 in. below the surface. The seeds are placed in the beds with their long axis horizontal, as if they are planted vertically the seedlings

obtained are frequently twisted. If the soil is regularly watered, the seeds, when fresh, usually germinate in about ten days. The seedlings require careful attention in the nursery ; the soil should be kept moist and the plants screened from the direct rays of the sun.

The subsequent procedure varies considerably. The seedlings are sometimes allowed to attain a height of about 2 ft. and are then carefully lifted from the beds and at once planted in the prepared holes. When this method is adopted, the shade should be gradually removed from the seedlings in the nursery, so that they are exposed to the full sun for some time before being transplanted.

In other cases the plants are allowed to remain in the nurseries for some months until they are 5 to 6 ft. high. The upper portion of the stem is then cut off, the plants are lifted from the beds, the roots trimmed, and the "stumps" thus obtained are carried in bundles to the plantation and placed in the holes. This method is generally adopted in Malaya, and very little loss is experienced as a rule.

The use of seed-baskets for raising the young plants has been recommended wherever possible, as very little interruption of the growth of the plant then occurs on transplanting. The baskets may be made of split bamboo, palm leaves, or similar material, and should be sufficiently strong to bear the weight of soil when filled. A single seed is sown in each basket and the plants thus raised are kept under shade and well watered until required for planting out. The entire basket is then placed in the soil without disturbing the roots. This method has given very good results on some estates in Ceylon.

In all cases the transplanting should be done if possible during rainy weather, so that the young plants may not suffer from lack of moisture.

The method of planting the seeds "at stake," *i.e.* in the position which the trees are to occupy, has given good results in certain cases, but the seedlings require considerable protection from animals and from the sun, which is much easier given in a nursery. In this method two or three seeds are planted in the prepared holes and well watered until germination takes place. When the seedlings have grown sufficiently, the most vigorous in each hole is selected to be retained and the others are removed.

As a general rule Para trees do not require shade after

being planted out, but in some situations where there is a dry season it has been found advantageous to provide shade trees for the first two years. A similar plan has been adopted where the seeds have been planted "at stake." The shade trees usually employed are the dadap, *Erythrina lithosperma*, and *Albizzia moluccana.*

Rate of Growth.—Under favourable conditions of climate and soil *Hevea brasiliensis* is a very quick-growing tree. In Malaya, where the conditions are exceptionally suitable, the rate of growth is more rapid than in any other country, and cases have been known there of trees attaining a height of 20 ft. and a girth of 8 in. one year after being planted out. Usually plantation trees in Malaya increase in girth from 4 to 6 in. per annum during the first few years, the subsequent rate of growth being determined by the distance at which the trees are planted. If the trees are closely planted, the rate of increase in girth is checked after about the tenth year, or even earlier if the lateral branches have completely met. The growth of widely planted trees is the most satisfactory, and the following figures have been given by Ridley for trees growing 20 ft. by 20 ft. apart in good soil without manuring :

	Girth at 3 ft. from base. in.		Girth at 3 ft. from base. in.
1st year	—	11th year	60
2nd ,,	9	12th ,,	66
3rd ,,	14	13th ,,	72
4th ,,	20	14th ,,	78
5th ,,	24	15th ,,	80
6th ,,	30	16th ,,	82
7th ,,	36	17th ,,	84
8th ,,	42	18th ,,	86
9th ,,	48	19th ,,	88
10th ,,	54	20th ,,	90

The oldest Para tree in the Botanic Gardens, Singapore, when thirty-four years old measured 84 ft. in height and 124 in. in girth at 3 ft. from the ground ; it is still increasing in girth at the rate of $1\frac{1}{2}$ in. per annum.

In Ceylon the rate of growth is a little less than in Malaya. During the first few years the trees usually

increase in height from 6 to 10 ft. per annum and in girth from 3 to 4 in. per annum. The parent trees at Henaratgoda were 80 ft. in height and over 100 in. in girth when thirty-five years old.

With reference to the rate of growth of *Hevea brasiliensis* in Africa the following particulars may be given:

SOUTHERN NIGERIA.—The six oldest Para trees in Southern Nigeria are growing in the Gardens at Ebute Metta. Three of these trees had an average girth of 44·3 in. in 1911 when seventeen years old, whilst the corresponding figure for the other three, which were eighteen years old, was 41·8 in.

The following particulars have been published of the growth of the trees at the Para Rubber Plantation, Calabar:

Age.	Number of trees.	Planting distance.	Average girth.
		ft.	in.
4 years . . .	494	15 × 15	12·19
3 ,, . . .	158	15 × 18	8·21
2 ,, . . .	415	15 × 18	9·8
2 ,, . . .	887	15 × 18	9·11
2 ,, . . .	864	15 × 18	10·9
1–2 ,, . . .	652	15 × 18	8·10

The largest four-year-old tree at Calabar measured 21·75 in. in girth, and several other trees of the same age exceeded 20 in.

Similar figures for Para trees growing on the Model Farm at Agege are also available:

Age.	Number of trees.	Planting distance.	Average girth.
		ft.	in.
4½ years . . .	1,462	20 × 20	12·25
4 ,, . . .	648	20 × 20	9·5
3½ ,, . . .	300	20 × 20	5·25

The growth at Agege is not so rapid as at Calabar, owing to the lower rainfall and the longer dry season.

The following measurements were recorded for 260 Para trees nine years old which were tapped experimentally at Orugbo during 1911:

Age.	Number of trees.	Average girth.
		in.
9 years	50	30·5
9 ,, ...	50	31·35
9 ,, ...	80	26·15
9 ,, ...	80	27·81

It is stated that at Messrs. Miller Brothers' Para plantations at Sapele 8,000 four-year-old trees had an average height of 20 ft. and a girth of 13 in., whilst the corresponding figures for 22,000 three-year-old trees were 13 ft. 6 in. and 8 in. respectively.

Gold Coast.—The Para tree is being cultivated experimentally at each of the Botanic Stations in this Colony, and the following particulars have been recorded regarding the rate of growth of the trees.

At Aburi, where the climatic conditions are not entirely favourable, 154 trees planted 15 ft. by 15 ft. in 1900 and 1901 had attained an average girth of 20½ in. at 3 ft. from the ground by the end of 1908. In March 1910 eighty of these trees were tapped experimentally in four groups, and the average girths of the trees of each group were 24, 26, 26½, and 27¼ in. respectively.

At the Tarquah Botanic Station over 60 acres are planted with Para trees at distances ranging from 12 ft. by 12 ft. to 40 ft. by 40 ft., but mostly at 15 ft. by 15 ft. The rate of growth during the first four years is shown in the following table :

Date of planting.	Planting distance.	Average height.	Average girth at 3 ft. from ground.			
		Dec. 1906.	Dec. 1905.	Dec. 1906.	Dec. 1907.	Dec. 1908.
	ft.	ft.	in.	in.	in.	in.
June 1904 . .	15 × 15	28	7	12	13	20
June 1904 . .	12 × 12	25	6	10	12	16
July-Sept. 1904 .	12 × 12	27	4	10	—	19·3
July 1904 . .	15 × 15	24	6	10	12	18·5
July 1904 . .	20 × 20	25	6	11	12	19
July 1904 . .	30 × 30	27	4	9	10	16
July 1904 . .	40 × 40	27	4	9	10	16·5

The average girth of the above trees when four and a half years old was 17 in., and in 1910 many of them were

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PARA TREES AT TARQUAH, GOLD COAST

Trees six years old

over 30 in. in circumference. 1,002 six-year-old trees, planted 12 ft. by 12 ft., were measured in 1910 previous to being tapped, and were found to have an average girth of 25 in.

The experimental plantation of Para trees at Coomassie has given very promising results so far as growth is concerned; some of the two-year-old trees were 35 ft. high and 6 in. in circumference at 3 ft. from the ground, whilst two-and-a-half to three-and-a-half-year-old trees had a girth of about 11 in. At the Assuantsi Station also, Para trees are doing well.

UGANDA.—In Uganda the Para tree is being cultivated experimentally in the Botanic Gardens at Entebbe and has made very satisfactory growth under the conditions which prevail there. The following measurements show the average dimensions of five representative trees:

Date of planting.	Date of measurement.	Height.		Girth at 3 ft. from ground.
		ft.	in.	in.
November 1904 .	March 31, 1907	21	10	8
November 1904 .	March 31, 1908	25	6½	12½
November 1904 .	March 31, 1909	32	10	15½

The average girth of 118 trees five to six years old was 20½ in. at 3 ft. from the ground, the largest tree measuring 28 in., whilst a number of the four-year-old trees were from 18 to 20 in. in girth.

The original Para tree which was brought as a seedling from Kew measured 42 ft. 4 in. in height and 2 ft. 6 in. in girth at 3 ft. from the ground when seven and a half years old.

NYASALAND.—The following measurements show the rate of growth of Para trees in the West Nyasa District, which is the only part of Nyasaland where the conditions are suitable for their cultivation:

No. of trees.	Age.	Planting distance.	Average girth.	Maximum girth.	Minimum girth.
	Years.	ft.	in.	in.	in.
85 . .	1½	20 × 20	3·27	3·75	2·50
100 . .	2½	20 × 20	4·26	5·25	3·00
100 . .	3½	20 × 20	8·98	12·25	5·50
102 . .	4½	30 × 30	9·61	14·50	8·00
50 . .	3½	15 × 15	12·12	14·00	9·00

Weeding and Catch Crops.—After the trees have become established the only work required on the plantation for the first three or four years, unless catch crops are to be grown, is to keep the weeds under control and to prevent them from interfering with the growth of the trees. The method of clean weeding has been generally adopted on rubber estates, and notwithstanding alternative proposals which have been advocated, it is still the system most in favour with planters. Clean weeding involves considerable expense in many cases and has the disadvantage of impoverishing the soil by exposing it to the action of tropical sun and rain, but these drawbacks are compensated for by a more rapid growth of the young rubber trees than is obtained under other conditions.

One of the principal alternatives to clean weeding is the cultivation of catch crops between the rubber trees during the first few years. This plan serves to protect the soil and to reduce the cost of weeding, whilst it also gives some return from the land until the rubber trees come into bearing. It is, however, open to the objection that the cultivation of the catch crop may retard the growth of the Hevea trees and defer the commencement of tapping for a year. In view of this possibility and of the short period during which catch crops can be raised, it is a question for the consideration of the planter whether the cultivation of such crops is likely to prove advantageous in any particular case. The crops which have been most commonly used for this purpose are cassava, groundnuts, sesame seed, chillies, lemongrass, citronella grass, and tobacco. Cocoa and coffee have also been extensively interplanted with Para trees, but these products are generally regarded as a more permanent crop, and when they are to be grown it is usual to plant the rubber trees sufficiently widely to allow room for both crops.

Another suggested plan for replacing the system of clean weeding is to grow certain leguminous plants which form a thick cover-crop and thereby check the development of weeds. These plants can be cut periodically to furnish a green manure, and thus they not only serve as a protection to the soil but also enrich it in nitrogen and humus. Species of Crotalaria, Mimosa, Desmodium, Tephrosia, Phaseolus, etc., belonging to the Leguminoseae have been recommended for use in this way, and in the

Federated Malay States the wild passion-flower (*Passiflora foetida*) has been utilised for the same purpose. This plan has not come into general favour, and experiments have shown that the growth of such cover-crops may retard the development of the trees. The method is, however, still under trial in Malaya and Ceylon.

Manuring.—A number of interesting trials have been made on rubber estates to determine the effect of the application of different classes of manures on the growth of the Para tree, and the results so far obtained indicate that the development of the young trees, including the rate of increase in girth, can be greatly stimulated by the judicious use of suitable fertilisers. Carefully controlled experiments are, however, required before any definite conclusions can be drawn.

Diseases and Pests.—The exclusive cultivation of one species of plant over large continuous areas offers very favourable conditions for the rapid spread of any disease or pest which may make its appearance, and some misgivings on this point have been felt in connection with the extensive plantations of *Hevea brasiliensis* in Malaya and Ceylon. Fortunately, however, no serious trouble has yet been experienced, and the only important disease of the Para tree is that caused by the fungus *Fomes semitostus*, Berk., which attacks the roots. In Malaya white ants (*Termes gestroi*) have proved very troublesome on many estates, and a few other insects, chiefly beetles and crickets, do some damage in certain cases. It is of interest to note that the occurrence of both *Fomes semitostus* and white ants in rubber plantations is to be traced to the presence in the ground of the decaying stumps of the original trees which serve to infect the rubber trees.

Only a very brief notice of the principal fungoid diseases which attack *Hevea brasiliensis* can be given here, and for fuller information reference must be made to the literature on the subject.*

* *The Physiology and Diseases of Hevea brasiliensis*, by T. Petch. (London: Dulau & Co.).

Annual Reports of the Ceylon Mycologist.

Circulars of the Royal Botanic Gardens, Ceylon.

Annual Reports of the Director of Agriculture and the Mycologist in the Federated Malay States.

Bulletins of the Department of Agriculture, Federated Malay States.

Leaf Diseases.—The leaf diseases which have appeared on *Hevea brasiliensis* up to the present time are not of much importance to the planter, as they do little damage and are chiefly confined to seedlings in the nurseries. It is stated that they can be effectively treated in the nurseries by spraying the plants with a boiled lime-sulphur mixture.

Stem Diseases.—The principal stem diseases of *Hevea brasiliensis* are : (1) a so-called canker, caused by *Phytophthora Faberi*, Maubl., which kills the portion of the cortex affected, but does not form an open wound ; (2) a true canker caused by a species of Coniothyrium ; (3) a "pink disease" due to *Corticium salmonicolor*, B. and Br. (*C. javanicum*, Zimm.), which is easily recognised by the formation of a pink film on the stem ; and (4) "die back," the chief cause of which is a Diplodia form of fungus which has been described under various names.

In the case of "canker" and "die back," the affected portions must be removed and the cut surfaces protected until they have healed. Spraying the stems with Bordeaux mixture is useful in dealing with all these diseases, as it destroys the spores and consequently prevents the spread of the fungus.

Root Diseases.—Three forms of root disease have been recorded as attacking *Hevea brasiliensis:* (1) *Fomes semitostus*, Berk., which covers the roots with white threads ; (2) *Hymenochaete noxia*, Berk., which covers the roots with brown or black threads ; and (3) *Sphaerostilbe repens*, B. and Br., which gives no outward sign of its presence, but forms dark red or black strands between the cortex and wood of the root. When attacked by root disease, a tree gradually dies back, owing to the inability of the roots to perform their proper functions, and very frequently it is finally blown over.

Fomes semitostus is by far the most important of the diseases which attack Hevea trees, and on some estates in Malaya and Ceylon considerable losses have been caused by it. A similar, if not identical, fungus attacks *Hevea brasiliensis* in West Africa. As a general rule it is not possible to save the affected trees, and the usual remedial measures consist in cutting them down and digging out the roots, together with any adjacent jungle stumps, and burning the whole. A trench about 2½ ft.

deep is then made round the affected area, and the soil within is carefully dug over and all roots removed and burnt. The area is again turned over, after an interval of about one month, and it is advisable to dig in lime, if available, at the rate of 2½ lb. for every square yard of surface. If these operations are carefully performed, the soil will be free from the fungus after a few weeks' interval and fresh trees may be planted.

White Ants.—These pests are now decreasing in Malaya. The usual treatment is to discover and destroy their nests, and to inject arsenic and sulphur fumes into their runs.

General Sanitation of Rubber Estates.—There are several points connected with the general sanitation of rubber estates which deserve attention by planters, as they have considerable influence on the health of the trees. The part which the decaying jungle stumps play in disseminating fungoid diseases and in harbouring pests has been referred to already, and their complete removal would be very beneficial to the health of the plantations. The distance at which the trees are planted is also an important point, as close planting tends to produce a humid atmosphere which is very favourable to the growth of fungi, whereas wide planting admits light and air to the plantation and thus diminishes the risk of disease. When catch-crops or cover-crops are grown, care should be taken that the plants selected are not attacked by the same diseases as *Hevea brasiliensis* (as is the case with cocoa) and that their growth does not give rise to conditions which are detrimental to the general sanitation of the estate. In principle it would be desirable to break up the large areas planted with Hevea trees into distinct blocks by means of protective belts of other trees so as to check the spread of any disease which may occur, but there seems little chance of this plan being adopted at present.

Tapping.—Cultivated Para trees are considered to be ready for tapping when they have attained a circumference of 18 to 20 in. at 3 ft. from the ground. In Malaya this girth is usually reached in about four years and in other countries in from five to seven years, according to the climatic conditions and the nature of the soil. Rubber can be obtained from trees less than 18 in.

in circumference, but it has hitherto been held to be disadvantageous to tap the trees until they have attained this size. Analyses made by Bamber in Ceylon (see p. 53) have shown that the rubber from two-year-old Para trees does not differ very markedly in composition from that derived from older trees, but it is generally agreed that the rubber from young trees is very deficient in physical properties, being soft and weak. In view of this fact and of the small yield of rubber obtainable from young trees, it is not usually desirable to tap Para trees before they are at least four years old.

The thickness of the cortex of Para trees of suitable size for tapping varies from $\frac{1}{8}$ to $\frac{1}{2}$ in. according to the age of the trees. It has been pointed out already that the greater number of the laticiferous vessels are situated in the innermost layers of the cortex, so that in order to obtain the maximum flow of latex it is necessary to cut sufficiently deeply to reach these layers. Great care should, however, be taken not to penetrate the wood nor to injure the cambium, as if this is done, the healing of the wound is retarded and the renewed bark, instead of being smooth, is likely to develop excrescences which seriously interfere with subsequent tappings.

Tapping is usually restricted to the basal portion of the trunk up to a height of about 6 ft., as it has been conclusively proved that the greatest yield of latex and rubber is obtained from this area. Experiments on tapping the higher portions of the stem show that not only is a smaller yield of latex obtained, but that the rubber is usually more resinous. In view of these results and of the additional labour involved, it is not usual to tap above a height of 6 ft.

Tapping is best performed in the early morning or late in the evening, as it has been found that during the day, when transpiration is active, the flow of latex is retarded. Experiments made by Ridley at the Botanic Gardens in Singapore showed that morning tappings furnished a larger yield of rubber than those made in the evening.

Large numbers of special tapping tools have been introduced for use on plantations, and almost every planter has his own views as to the best type of instrument to use. Many of the knives are of very complicated

design, but it is of interest to note that some of the best tapping is done with the simplest appliances, such as an ordinary gouge or a simple modification of the farrier's knife. No detailed notice of the different forms of knives is possible here, but it may be stated that the essential feature of a good tapping tool is a very sharp cutting edge which can be easily maintained, as a clean cut is necessary in order to secure a good flow of latex.

The methods of tapping *Hevea brasiliensis* trees which have been evolved on the plantations in the East depend upon the important fact that if the initial incisions are reopened after a short interval by cutting off a thin slice of bark from one of the edges of the cuts, a further flow of latex takes place, and that this procedure may be repeated again and again with a similar result. This capacity of the Para tree to furnish latex repeatedly at short intervals is one of its most important characteristics, and gives the tree its unique value for plantation purposes. Another interesting point in this connection is that in tapping trees for the first time, or after a long interval, the yield of latex from the first two or three incisions is usually very small, but that it increases considerably from the subsequent tappings. The Hevea trees in the Amazon valley also exhibit this characteristic, which is well known to the rubber collectors there.

This behaviour of the Para tree has been termed "wound response," on the assumption that the incisions made in the bark act in some way as a stimulus to the production of latex.

An important point in connection with the use of this paring method is that the tapping should be so arranged that the whole of the original bark is not removed until the renewed bark on part of the tree is ready for retapping. It is now generally agreed that it is not advisable to tap renewed bark until it is at least four years old, and consequently most of the methods of tapping at present in use are arranged to ensure this. The usual plan is to divide the trunk into four vertical sections which are tapped in successive years, so that after all the original bark has been excised the renewed bark on the first section will be four years old and ready for retapping.

The method of tapping Para trees which is most gener-

ally adopted at the present time on the plantations in Ceylon and Malaya is the half-herringbone system, the incisions being restricted to one quarter of the circumference of the tree at a time and reopened every day or every second or third day. The procedure is usually as follows :

When the tree has attained a sufficient girth for tapping, the trunk is divided into four equal vertical sections, and on one section tapping lines are drawn to a height of about 6 ft. for the guidance of the tapper. The coolie first cuts a vertical channel as high as he can reach on one side of the area to be tapped, and at the base of this he inserts a small metal spout into the bark to direct the latex into the collecting-cup placed below. He then cuts the lateral incisions leading into the vertical channel, which are usually made at an angle of 45 degrees and about 12 in. apart. These incisions must be made sufficiently deeply to ensure a good flow of latex, but should not penetrate the wood. The latex which exudes runs down the oblique lateral cuts into the vertical channel and thence into the cup at the base of the tree. Early the next morning, assuming that the trees are being tapped every day, the coolie pares a very thin slice of bark from the lower edge of each of the lateral cuts, when a fresh flow of latex occurs. This procedure is repeated day by day until the whole of the bark between the adjacent lateral incisions has been removed. It is very important in this method of tapping that the successive shavings of bark which are cut from the lower edge of the incisions should be very thin, in order that the available bark may last as long as possible. It has been found in practice that shavings $\frac{1}{20}$ in., or even less, in thickness can be easily cut, so that if 12 in. of bark are left between the original lateral incisions about 240 tappings will be possible before the whole of the bark has been cut away.

A quarter of the trunk treated in this manner will therefore suffice for a year's tapping. During the second year the opposite quarter is tapped, and then the two remaining quarters in rotation. In the fifth year the renewed bark on the first section will be tapped, and so on.

The bark heals from the upper edge of the cuts as the tapping proceeds, and if the operations have been carefully performed, without unduly injuring the cambium,

From the Collections of the Imperial Institute

TAPPING PARA TREES IN MALAYA

Half-herringbone system ; incisions reopened by paring

the growth is rapid and satisfactory. After an interval of four years the renewed bark has been found to give as good a yield of latex as the original bark.*

Besides the half-herringbone method described above, a number of other systems have been tried for tapping Hevea trees. The principal of these are: (1) the double herringbone system, which is sometimes employed on large trees; (2) full-spiral and half-spiral incisions, which furnish large yields of latex and rubber, but have now been generally abandoned as being too drastic for continuous use, especially in the case of young trees; (3) large or small V incisions, which necessitate the fixing of a cup at the base of each V and therefore involve a large amount of labour; (4) basal V or Y incisions or oblique cuts for tapping the base of young trees which are not large enough to be tapped to a height of 6 ft.; and (5) vertical incisions. In all these systems, except the last, it is usual to reopen the cuts by paring a thin slice from the lower edge as previously described.

At one time a combined method of paring and pricking was adopted for reopening the incisions and a number of special forms of pricker were introduced for the purpose. These prickers have, however, fallen into disfavour, as it has been found that their continued use often leads to the formation of excrescences from the wood, and also that in some cases the renewal of bark over the pricked area is not satisfactory. In consequence of these facts, the reopening of the incisions is now usually done by paring only.

Collection of the Latex.—The collecting-cups used on rubber plantations were at first made of tin, iron, or steel, but such cups are not entirely satisfactory as they quickly become rusty and are then difficult to keep clean. In order to obviate this drawback, aluminium or enamelled iron cups have been tried, and, more recently, glass, earthenware, and paper cups have been largely adopted.

A little water is sometimes placed in the cups in order to preserve the latex in a liquid condition until it can be collected and carried to the factory. In some cases, when the latex is thick and does not run freely, a system

* For the results of tapping experiments on Para tree see *Circulars and Agricultural Journal of Royal Botanic Gardens, Ceylon*; *Agricultural Bulletin of Straits and Federated Malay States*; *Agricultural Bulletin of Federated Malay States.*

of drip-tins is employed to facilitate its flow and thus prevent its coagulation on the stem. The drip-tins are fixed at the upper ends of the incisions and provide a very slow current of water along the cuts.

If it is desired to keep Para latex liquid for any length of time, it should be rendered alkaline with ammonia, or a little formalin should be added.

When the flow of latex has ceased, the contents of the collecting-cups are emptied into enamelled iron pails and the latex is at once transported to the factory.

Preparation of the Rubber.—On arrival at the factory the latex is first strained in order to remove all mechanical impurities, either by passing it through sieves of wire gauze or coarse cloth, or by means of centrifugal strainers. Sometimes the straining is done at the time of collecting the latex from the cups, the pails being fitted with a sieve for the purpose.

The method most generally adopted on the plantations for coagulating Hevea latex is to render it faintly acid by the addition of acetic acid. The use of a large excess of acid is undesirable and should be avoided. Several other acids, *e.g.* formic acid, lactic acid, and hydrofluoric acid (purub), and other coagulants are also employed to prepare Para rubber, but none of these is so extensively used as acetic acid.

When the rubber is prepared in the form of biscuit or sheet without the use of machinery, the acidified latex is simply allowed to stand in circular or rectangular vessels until coagulation has occurred, and the cakes of rubber obtained are washed, pressed, and dried.

If, however, large quantities of rubber are being dealt with by machinery the latex is usually coagulated in bulk in large tanks, the necessary amount of acetic acid being stirred in and the liquid allowed to stand until coagulation is complete. Sometimes the coagulation of the latex is accelerated by churning it, after the addition of acetic acid, in machines such as the Michie-Golledge Coagulator or the K.L. Coagulator. The freshly coagulated rubber obtained by these methods is then rolled out into sheet or crêpe by the machines.

The chief forms in which plantation Para rubber appears on the market are (1) biscuits, (2) sheet (smoked and unsmoked), (3) crêpe, (4) block, and (5) scrap.

The preparation of the forms (1) to (4) and the methods employed in drying and smoking the rubber have been already described in the general part of this book (see pp. 74–7) and need not be repeated here.

Scrap rubber consists of the shreds which coagulate in the incisions or in the collecting-cups and other utensils. It is exported in the form of balls or cakes, or it is converted into crêpe by passing it through a washing machine and is then sometimes made into block.

A small quantity of rubber may be recovered from the shavings of bark removed during tapping by macerating them in water and then passing the mass through the washing machine until the vegetable tissue is eliminated.

Considerable interest is being taken by planters at the present time in the adaptation for plantation use of the Brazilian method of preparing Para rubber by smoking the latex (see p. 105). Several machines, notably those designed by Wickham and Derry, have been introduced for carrying out the process on a commercial scale, and trials with these are now being made. It is, however, too early to say whether the rubber prepared in this way will be preferred by manufacturers to the present forms or whether the process will prove suitable for general adoption on rubber estates.

Yield of Rubber from Cultivated Para Trees.—The yield of rubber furnished by individual Para trees varies considerably with the conditions under which they are grown, and it is now generally considered that the yield per acre, which is more constant, affords a more satisfactory basis for calculating returns than the average yield per tree.

In Malaya during 1911 the average yield of rubber from the whole area tapped was about 200 lb. per acre, and it must be remembered that many of the trees were being tapped for the first time. It is estimated that the return from five- to six-year-old trees in Malaya may be safely put at about 250 lb. per acre, whilst the yield from older trees is correspondingly higher.

The average number of trees per acre in Malaya is about 150, so that a yield of 250 lb. of rubber per acre would be equal to about $1\frac{2}{3}$ lb. per tree. In this connection the following figures, which show the average yield of rubber per tree in Malaya during 1906, 1907, and 1908, may be quoted ;

Year.	No. of trees tapped.	Average yield of rubber per tree.
		lb. oz.
1906	516,914	1 12
1907	1,300,227	1 12
1908	1,954,090	1 $15\frac{3}{4}$

These results are, of course, from trees of all ages, but a large proportion in each year were being tapped for the first time. In 1908 the percentage of trees tapped for the first time in Negri Sembilan was much lower than in the other States, and the results from 306,376 trees in that State averaged 3 lb. $2\frac{1}{3}$ oz. of rubber per tree. On several plantations in Malaya yields of from 7 to 8 lb. of rubber per tree per annum have been obtained from trees seven to nine years old and 10 to 11 lb. from trees eleven to twelve years old.

Wright has made an analysis of the returns published by a large number of Malayan rubber companies, and he gives the following summary, from which exceptional yields have been excluded, as illustrating the results which are being obtained on different estates * :

Age of trees.	Rubber per acre.	Rubber per tree.
Years.	lb.	lb.
3 to 4	50 to 100	0·53 to 1·06
4 ,, 5	70 ,, 136	0·88 ,, 1·50
5 ,, 6	114 ,, 160	1·21 ,, 1·79
6 ,, 7	128 ,, 221	1·60 ,, 2·47
7 ,, 8	240 ,, 319	2·44 ,, 3·39
8 ,, 9	313 ,, 443	3·09 ,, 4·17
9 ,, 10	363 ,, 550	3·90 ,, 4·45
10 ,, 11	396 ,, 630	4·77 ,, 5·35
11 ,, 12	450 ,, 758	5·69 ,, 6·76

In Ceylon the rate of growth of Para trees is not so rapid as in Malaya, and as a rule the trees are not ready for tapping until they are a year older. Lock considers that Para trees grown in Ceylon under suitable conditions of climate and soil will yield at least 100 lb. per acre in the seventh year, 150 lb. in the eighth, 250 lb. in the ninth, and so on, increasing as the trees become older. This is admittedly a conservative estimate, and the published

* *Hevea brasiliensis, or Para Rubber*, by Herbert Wright, 4th edition, pp. 283, 291.

figures of Ceylon plantations indicate yields of 150 to 200 lb. of rubber per acre from six- to seven-year-old trees.

The following table, compiled by Wright from the returns of Ceylon rubber companies, may be given for comparison with the similar figures for Malaya already quoted :

Age of trees.	Rubber per acre.	Rubber per tree.
Years.	lb.	lb.
4 to 6	31 to 117	0·41 to 0·63
5 ,, 7	64 ,, 166	0·60 ,, 0·86
6 ,, 7	105 ,, 200	0·75 ,, 1·59
7 ,, 9	153 ,, 234	1·01 ,, 1·77
9 ,, 11	—	1·48 ,, 3·00
12 ,, 15	405 to 469	1·74 ,, 3·65

It will be seen that the yields per tree are very much lower in Ceylon than in Malaya; but owing to the fact that the trees are much more closely planted in Ceylon, there is not the same disparity in the yields per acre.

In view of these figures for Malaya and Ceylon, it will be of interest to consider the yields of rubber so far obtained from cultivated Para trees in Africa, and, as the results are not readily accessible, they may be recorded in some detail under the respective countries.

SOUTHERN NIGERIA.—The six oldest Para trees in Southern Nigeria, growing in the Gardens at Ebute Metta, have been tapped for short periods during recent years. The trees have been divided into two groups of three each, Group I. consisting of typical *Hevea brasiliensis*, whilst the trees of Group II. are a form of that species. The results of the tappings are summarised in the following table :

Age of trees.		Period of tapping.	No. of tappings.	Average yield of dry rubber per tree.		Average yield of dry rubber per tree at each tapping.
	Years.			lb.	oz.	oz.
Group I.	15 .	Aug.—Oct. 1908	16		5·28	0·33
	16 .	Sept.—Oct. 1909	25	1	4	0·8
	17 .	Oct.—Dec. 1910	27		15·75	0·58
	18 .	Apr.—Nov. 1911	62	3	15·5	1·02
Group II.	17 .	Sept.—Oct. 1909	25		12·5	0·5
	18 .	Oct.—Dec. 1910	26		13·65	0·52
	19 .	Apr.—Nov. 1911	62	3	2·6	0·82

During 1910 and 1911 a series of tapping experiments was conducted with Para trees growing at the Calabar Gardens. Forty-five trees, eight of which were estimated to be fourteen years old, and the remainder from six to eight years, were tapped during two periods, June to October 1910 and October 1910 to February 1911, and furnished the following results:

Age of trees.	Tapping period.	No. of tappings.	Average yield of dry rubber per tree.	Average yield of dry rubber per tree at each tapping.
Years.			oz.	oz.
14	June—Oct. 1910	45	6·8	0·15
	Oct. 1910—Feb. 1911	83	30·38	0·37
6 to 8	June—Oct. 1910	29	0·94	0·032
	Oct. 1910—Feb. 1911	83	8·33	0·1

A second experiment was conducted at Calabar with thirty-seven six-year-old trees which had an average girth of 24 in. at 3 ft. The tapping was done daily for thirty-six days and the following results were obtained:

No. of trees.	No. of tappings.	Total yield of dry rubber.	Average yield of rubber per tree.	Average yield of rubber per tree at each tapping.
		lb.	oz.	oz.
37	36	14	6·05	0·168

A series of tapping experiments was conducted during 1909 on Para trees at the Rev. J. E. Wright's plantation at Orugbo. One hundred eight-year-old trees were selected for trial, and were divided into two groups: (1) fifty trees with an average girth of 25 in.; and (2) fifty trees with an average girth of 22 in.; in addition, three trees which had been tapped in August 1909 were re-tapped. The experiments extended from September 19 to October 30, 1909, and the tappings were made on alternate days, with the exception that the fifty trees of the first group were tapped every day for one week. The half-herringbone system was employed, the vertical channel being made 6 ft. high and the lateral cuts 6 in.

long. The results obtained are summarised in the following table:

No. of trees.	No. of tappings.	Daily yield of dry rubber.		Total yield of dry rubber.	Average total yield per tree.	Average yield per tree at each tapping.
		Minimum.	Maximum.			
		oz.	lb. oz.	lb. oz.	oz.	oz.
1. 50 trees—average girth 25 in. .	23	2*	1 5½†	20 8	6·56	0·29
2. 50 trees—average girth 22 in. .	21	2½*	14½‡	14 2¾	4·53	0·21
3. 3 trees previously tapped § .	20	nil*	2‖	1 2	6	0·3

These experiments were continued during 1910, when two further groups, each containing eighty trees, were tapped in addition to the trees operated upon in the previous year. The tapping was done every alternate day from September 19 to December 31, with the exception of a break of three days from September 27 to 29. The results are summarised below:

No. of trees.	Average girth at 3 ft. from ground.	Tapping system.	Total yield of dry rubber.		Average yield of dry rubber per tree.	
	in.		lb.	oz.	lb.	oz.
50 . .	30·5	Single herringbone	61	9	1	3·7
50 . .	31·35	Double herringbone	63	4	1	4·2
80 . .	26·15	Single herringbone	68	13		13·76
80 . .	27·81	Double herringbone	66	5		13·26
260			259	15	1 lb.	

Tapping was commenced during 1911 at Messrs. Miller Brothers' plantation at Sapele, 300 of the largest five-year-old trees which were 22·82 in. in average girth being selected for the purpose. The trees were divided into three groups of 100 each, which were tapped to a height of 5½ ft. over one-quarter, one-third, and one-half of the circumference respectively, the lateral incisions being made 12 in. apart. The tapping was performed

* First tapping.
† 21st tapping.
‡ 15th and 17th tappings.
§ These three trees gave 9 oz. of dry rubber in 8 tappings in August 1909.
‖ 15th tapping.

every third day, and it was arranged that it should cease in the three groups when 12, 9, and 6 in. of bark had been excised, in order that the whole of the original bark should not be removed before the end of four years. The following figures showing the progress of the experiments have been published :

No. of trees.	Area of trunk tapped.	No. of tappings.	Total yield of dry rubber.	Average yield of dry rubber per tree.	Average yield of dry rubber per tree at each tapping.
			lb. oz.	lb. oz.	oz.
100 . . .	$\frac{1}{4}$	63	133 $4\frac{1}{4}$	1 5·32	0·34
100 . . .	$\frac{1}{3}$	63	141 3	1 6·59	0·36
100 . . .	$\frac{1}{2}$	37	87 $12\frac{3}{4}$	14·05	0·38

It will be noticed that there was very little difference in the yield of rubber per tapping whether the incisions extended over one-fourth, one-third, or one-half of the circumference.

The results of these trial tappings of Para trees in Southern Nigeria must be regarded as very satisfactory. Eighteen- and nineteen-year-old trees at Ebute Metta have furnished 3 to 4 lb. of rubber during seven months, whilst fourteen-year-old trees at Calabar gave 2 lb. 5 oz. of rubber each when tapped from June 1910 to February 1911. At Orugbo 260 nine-year-old trees gave an average of 1 lb. of rubber in three and a half months, and at Sapele 200 five-year-old trees, tapped for the first time, furnished over $1\frac{1}{4}$ lb. each, from sixty-three tappings every third day. These figures compare favourably with those recorded in the East, and promise well for the success of the industry in Southern Nigeria.

Gold Coast.—A number of tapping experiments have been conducted in the Gold Coast on Para trees growing at Aburi and Tarquah, and the results obtained are given in the following account :

At Aburi fourteen trees planted 15 ft. by 15 ft. in 1900 and 1901 were tapped by the half-spiral system three times a week from November 19 to December 31, 1908, and gave 2 lb. $8\frac{1}{2}$ oz. of dry rubber. This yield is equivalent to 2·9 oz. of dry rubber per tree in eighteen tappings extending over six weeks, or 0·16 oz. per tree per tapping.

During 1909 further tapping experiments were carried out at Aburi on groups of Para trees 25 in. or more in average girth at 3 ft. from the ground, and the results are summarised in the following table:

No. of trees.	System of tapping.	No. of tappings.	Total yield of dry rubber.	Average total yield per tree.	Average yield per tree at each tapping.
			lb. oz.	oz.	oz.
I. 15 trees, average girth 27 in.	V incisions	14	2 5½	2·5	0·18
II. 15 trees, average girth 28·6 in.	Large V incisions and paring	20	4 5¼	4·62	0·23
III. 14 trees,* average girth 25 in.	Half spiral	20	4 5¾	4·98	0·25

These experiments were continued during 1910 and 1911 on four groups of trees, which were tapped every other day for periods of seven to ten months during 1910 and throughout the following year. The results obtained are summarised below:

No. of trees.	Average girth.	System of tapping.	No. of tappings.	Total yield of dry rubber.	Average yield of dry rubber per tree.	Average yield of dry rubber per tree at each tapping.
	in.			lb. oz.	lb. oz.	oz.
I. 24 trees: 1910	26	Half spiral	86 during 7 months	29 9	1 3·7	0·23
1911†	29·6	Do.	131‡	44 3½	1 12·3	0·21
II. 15 trees: 1910	24	Half spiral	129 during 10 months	31 11	2 1·8	0·26
1911§	28	Do.	152	32 11¼	2 5·4	0·24
III. 15 trees: 1910	26½	V incisions and paring	130 during 10 months	32 1	2 2·2	0·26
1911	30	Do.	152	31 12	2 2	0·22
IV. 25 trees: 1910	27¼	V incisions and paring	89 during 7 months	30 12	1 3·7	0·22
1911	30	Do.	151	50 0	2 0	0·21

* These were the 14 trees tapped in 1908; see p. 130.
† 25 trees tapped in 1911.
‡ Tapping discontinued November 9, 1911.
§ 14 trees tapped in 1911.

The trees which were tapped continuously throughout 1911 maintained as healthy an appearance as those not tapped; they continued to give a good yield of rubber and the renewal of the bark was satisfactory. In Groups II., III. and IV. the average yield of rubber per tree from 152 tappings was 2 lb. 1·9 oz. All the original bark of the trees of Group II., which were tapped for the first time in 1908, was used up during 1911, and the average yield of rubber per tree was 5 lb. 1½ oz. from 320 tappings during the four years. The renewed bark is now being tapped, and the results indicate a better return than from the original bark.

A series of tapping experiments was conducted at Tarquah during November 1909 on a number of Para trees planted in June 1904. Fifteen trees of 25 in. average girth were tapped by means of three half-spirals connected by a vertical channel; the tapping was done twelve times on alternate days, and yielded 2 lb. 8 oz. of dry biscuit rubber. Fifteen other trees of 25·8 in. average girth were tapped by means of three large V's connected by a vertical channel; the tapping was done twelve times as before, on alternate days, and yielded 2 lb. 10 oz. of dry biscuit rubber. The yield of rubber from the two experiments was 5 lb. 2 oz. of dry biscuit and 12 oz. of scrap, giving a total of 5 lb. 14 oz., an average of 3·13 oz. per tree for twelve tappings, extending over twenty-three days, or 0·26 oz. per tree per tapping.

The same thirty trees were again tapped every alternate day, except Sundays, from March to December 1910, and gave the following results:

No. of trees.	System of tapping.	No. of tappings.	Length of cuts per tree.	Total yield of dry rubber.	Average total yield per tree.	Average yield per tree at each tapping.
			in.	lb. oz.	lb. oz.	oz.
I. 15 trees, avge. girth 30·1 in.	Half spiral	127	53	20 11½	1 6	0·17
II. 15 trees, avge. girth 30·2 in.	Large V and paring	128	55	18 5¼	1 3½	0·15

During 1911 thirty trees at Tarquah, having an average girth of 32½ in., were tapped on alternate days throughout the year. The total yield of dry rubber

was 100 lb. 2 oz., equal to an average yield of $3\frac{1}{3}$ lb. per tree.

Tapping on a larger scale was also commenced at Tarquah during 1910. 1,002 six-year-old trees, growing 12 by 12 ft. apart, were tapped regularly from July 28 to December 31, twice a week from July 28 to October 8, and three times a week during the remaining period. The following results were obtained :

No. of trees.	Average girth at 3 ft. from ground.	Number of tappings.	System of tapping.	Total yield of dry rubber.	Average total yield per tree.	Average yield per tree at each tapping.
	in.			cwt.	oz.	oz.
1,002 . .	25	54	Half spiral	$4\frac{1}{2}$	8	0·15

The tapping was continued throughout 1911, the trees being tapped every alternate day except during March and April. The total yield of rubber obtained was $1,224\frac{1}{2}$ lb., or nearly $1\frac{1}{4}$ lb. per tree, from seven-year-old trees in ten months' tapping.

It will be evident from these results that the Para tree has given very satisfactory yields of rubber in the Gold Coast. At Aburi, trees have furnished over 2 lb. of rubber per tree per annum, and at Tarquah $3\frac{1}{3}$ lb. of rubber per tree have been obtained in a year's tapping. The cultivation of Para trees in the Gold Coast therefore promises to be very successful, especially in situations such as Tarquah, where the conditions are favourable to the growth of the trees.

UGANDA.—Series of tapping experiments have been conducted on the Para trees growing at Entebbe by Mr. R. Fyffe of the Forestry Department, and the following details will be of interest :

1. In November 1908 a seven-year-old tree ($25\frac{1}{2}$ in. in girth) and a four-year-old tree ($18\frac{1}{2}$ in. in girth) were tapped to a height of 6 ft., the older tree by the spiral system and the younger by herringbone incisions. The trees were tapped twenty-nine times on alternate days, the duration of the experiments being fifty-nine days. The total yield of dry rubber obtained during this period was 4·7 oz. from the seven-year-old tree and 4·3 oz. from the four-year-old tree. The younger tree gave more

latex than the older tree, but the amount of dry rubber obtained from it was slightly less.

After resting two months these two trees were again tapped in April 1909, the tapping being done by the same systems as in the first experiment; the older tree was, however, tapped to a height of 21 ft. on this occasion, and the younger tree only to 6 ft. as before. Forty-eight tappings were made in each case on alternate days, covering a period of ninety-six days. The total yield of dry rubber was 7·1 oz. from the seven-year-old tree and 6·6 oz. from the four-year-old tree.

In these two series of tapping experiments the trees were first tapped on alternate days for two months, then allowed to rest for two months, and again tapped on alternate days for three months. Combining the results obtained it will be found that the seven-year-old tree yielded 11·8 oz. and the four-year-old tree 10·9 oz. of dry rubber in seven months, during two of which no tapping was performed.

2. During 1909 four Para trees, four years old, were tapped to a height of 6 ft. by different methods, viz. herringbone, spiral, oblique cuts and V-cuts, in order to determine the respective yields. They were tapped every alternate day until the yields began to decrease, and the results obtained were as follows:

System of tapping.	Number of times tapped.	Total yield of dry rubber.	Average yield of dry rubber at each tapping.
		oz.	oz.
1. Herringbone . .	15	2·25	0·15
2. Spiral . . .	43	3·06	0·07
3. Oblique cuts . .	43	5·25	0·12
4. V-cuts . . .	43	6·20	0·14

The tree (No. 1) tapped by the herringbone method furnished a large quantity of latex for some time, but the flow ceased entirely after it had been tapped fifteen times. The yield of dry rubber from the tree No. 2 tapped by the spiral method was small, but the yields from trees Nos. 3 and 4 were very satisfactory, amounting to 5·25 oz. and 6·20 oz. of dry rubber respectively during a period of just under three months.

3. In 1910 seven trees, six of which were five years old and the other eight years old, were tapped thirty

times on alternate days to a height of 6 ft. Five of these trees had been used for the previous experiments. The same systems of tapping were employed as before, but in addition the half-herringbone method was also tried. The returns from the individual trees were not kept separate in this case, but the total yield of dry rubber from the seven trees was 2·37 lb., equal to 5·4 oz. per tree during a period of two months.

4. During the latter part of 1910 all the Para trees in the Gardens having a girth of 18 in. or over at 3 ft. from the ground were tapped. The number of trees was 118; they were five to six years old and had an average girth of 20½ in., the largest measuring 28 in. and the smallest 18 in. The tapping was done on the half-herringbone system to a height of 5 ft. and was continued on alternate days for four months, each tree being tapped fifty-two times. The total yield of dry rubber from the 118 trees was 50·3 lb., equivalent to a yield of 6·8 oz. per tree during a period of four months.

5. A further experiment with 164 trees in the Gardens was conducted from January 1 to March 31, 1911. The trees were tapped forty-one times on alternate days, and yielded 134 lb. of dry rubber, equal to an average yield of 13·07 oz. per tree in three months.

The yields of rubber obtained in these experiments are very promising, and if they are maintained when the trees are tapped regularly for longer periods, the return will be very satisfactory.

Belgian Congo.—The results of a number of tapping experiments on Para trees growing in the Belgian Congo have been recorded and are summarised in the following table:

District.	Age of trees.	No. of tappings.	Average yield of dry rubber per tree.		Average yield of dry rubber per tree at each tapping.
	Years.		lb.	oz.	oz.
Mayumbe . .	10	30	0	10½	0·35
,, . .	10	10	0	3½	0·35
Boma . . .	10	during 28 days	0	6½	—
Coquilhatville .	10	40	3	5	1·32
Tlambi . .	11	11	0	5	0·46
,, . .	11	10 (every second day)	0	8	0·80

Composition of Para Rubber from Cultivated Trees.—The Para rubber prepared on the plantations in the East is of a very high degree of purity. Very little moisture or ash is present, and the percentages of resin and protein are usually low, with the result that the rubber may contain as much as 95 or 96 per cent. of caoutchouc. The following analyses made at the Imperial Institute will illustrate the composition of specimens from different countries:

Country.	Description of rubber.	Composition of dry washed rubber.			
		Caout-chouc.	Resin.	Protein.	Ash.
		Per cent.	Per cent.	Per cent.	Per cent.
Ceylon . . .	Biscuits	96·7	1·7	1·4	0·2
,, . . .	,,	96·6	1·6	1·6	0·2
,, . . .	,,	96·4	1·8	1·6	0·2
,, . . .	,,	96·0	1·6	2·1	0·3
,, . . .	,,	95·8	2·2	1·8	0·2
,, . . .	Crêpe	94·0	2·6	3·0	0·4
,, . . .	,,	94·0	2·7	2·8	0·5
,, . . .	,,	92·7	3·1	3·7	0·5
India: Burma . .	Pale crêpe	94·3	3·2	2·2	0·3
,, ,, . .	Crêpe	93·6	3·1	3·0	0·3
,, ,, . .	Smoked crêpe	92·8	3·6	3·1	0·5
,, ,, . .	,,	90·0	3·1	2·9	4·0
,, ,, . .	Dark crêpe	92·0	2·5	3·8	1·7
,, ,, . .	Scrap crêpe	92·1	2·8	3·3	1·8
,, ,, . .	Sheet	95·7	1·6	2·4	0·3
,, Nilgiris . .	Biscuits	92·8	2·6	3·0	1·6
,, ,, . .	,,	91·9	3·9	3·7	0·5
Federated Malay States	Sheet	96·5	1·9	1·4	0·2
,, ,,	Biscuits	96·0	1·4	2·1	0·5
,, ,,	Sheet	95·8	1·8	2·1	0·3
,, ,,	,,	95·5	1·8	2·4	0·3
,, ,,	Biscuits	95·2	2·2	2·3	0·3
,, ,,	Crêpe	94·8	2·7	2·3	0·2
,, ,,	,,	94·0	3·0	2·9	0·1
,, ,,	,,	92·9	3·6	3·2	0·3
Papua . . .	Sheet	95·7	2·8	1·3	0·2
Seychelles . . .	Cakes	93·1	3·7	3·0	0·2
,, . . .	Biscuits	93·8	2·6	3·5	0·1
,, . . .	,,	94·6	2·8	2·3	0·3
Southern Nigeria . .	,,	95·8	1·7	2·1	0·4
,, ,, . .	,,	95·6	1·7	2·3	0·4
,, ,, . .	,,	92·9	4·9	1·9	0·3
,, ,, . .	,,	93·8	3·5	2·3	0·4
,, ,, . .	,,	94·1	3·7	2·0	0·2
Trinidad . . .	,,	94·9	3·2	1·6	0·3
,, . . .	,,	92·8	3·7	2·7	0·8
Dominica . . .	,,	93·4	4·2	2·1	0·3

CHAPTER X

THE CEARA RUBBER TREE,

MANIHOT GLAZIOVII, MÜLL. ARG.

Species of Manihot.—The Ceara rubber tree and its recently discovered allies are natives of north-eastern Brazil and furnish the rubber known as Maniçoba in that country. Until 1901 it was believed that *Manihot Glaziovii* was the only rubber-yielding species of the genus, but in that year Professor Löfgren, the Director of the Botanic Gardens at São Paulo, found that *Manihot violacea*, Müll. Arg., also yields rubber of good quality. This plant, however, is of herbaceous character and has not become of importance as a source of rubber. Subsequently to this discovery attention was drawn to the Maniçoba rubber trees occurring in Bahia by the very large increase in the exports of Maniçoba rubber from that State, which rose from about 24 tons in 1901 to 1,444 tons and 1,410 tons in 1905 and 1906 respectively. As the result of the inquiries which were made it was found that the increased production was due to the exploitation of species of Manihot other than *M. Glaziovii*; and Professor Ule, who investigated the question on the spot at the request of the Bahia Rubber Syndicate, was able to establish the existence in north-eastern Brazil of three new rubber-yielding Manihots, which were named *M. dichotoma*, Ule, *M. heptaphylla*, Ule, and *M. piauhyensis*, Ule.

In 1906 specimens of seeds, described as those of the Jequié Maniçoba (*M. dichotoma*), were received at Kew, and both seeds and plants raised therefrom were distributed to a number of British Colonies for trial. Subsequently seeds of *M. heptaphylla* and *M. piauhyensis* were obtained, and the three new species are at present

undergoing trial in several countries for comparison with *M. Glaziovii.*

In the following account the Ceara tree (*M. Glaziovii*) is first dealt with, and then a short description is given of the new species.

Botanical Characters.—The Ceara rubber tree was first described in 1874 by J. Müller, who named it *Manihot Glaziovii* after its discoverer, Dr. Glasiou, a French botanist. It belongs, like the Para tree, to the natural order Euphorbiaceae, and is a moderate-sized tree 30 to 50 ft. high with an erect stem 8 to 20 in. in diameter. As a rule the branches are numerous and spreading, forming a dense, rounded crown, but in some trees only a few erect branches are developed. The bark is thin, purple-grey, and the outer silvery layers can be readily stripped off. The leaves are palmate, the lobes being deeply cut and varying in number from three to nine in leaves on the same tree ; they are of thin texture, smooth on both surfaces, dark bluish-green above and paler beneath. The flowers, which are rather large, are unisexual and both male and female occur in the same raceme. The fruit is a three-celled capsule, each cell containing a single seed ; it is nearly globular, and when ripe is hard and dry, splitting to release the seeds. The latter are plano-convex in shape and have a thick, hard seed-coat, the outer layer of which is smooth and shiny, varying in colour from grey to dark brown and mottled with purplish-black patches. (See Plate V.)

Distribution.—In Brazil *Manihot Glaziovii* is most abundant in the States of Ceara, Piauhy, and Bahia. Cross, who visited the State of Ceara in 1876 in the course of his journey through South America for the purpose of collecting rubber seeds and plants for the Government of India, found the tree growing freely in the flat country lying between the town of Ceara on the coast and the mountains, where the elevation was not more than 200 ft. The climate of this region is very dry and arid for a considerable portion of the year, and many of the crops can only be grown by irrigation. The rainy season extends from November to May or June, but it is stated that in some years very little rain falls. The daily temperature recorded on the coast ranged from 82° to 85° F., but Cross considered that in the interior it was often 90° F.

Manihot Glaziovii, Müll. Arg., the Ceara Rubber Tree

A. Leaf B. Flowering shoot C. Seeds

The soil of the district is generally poor, but the tree appears to thrive in such conditions; in places it was found growing on soft sandstone, gravel, or amongst boulders of grey granite.

Some further observations on the natural conditions under which the Ceara tree occurs in north-eastern Brazil have been published by Biffen, who visited the country in 1897. He found the tree growing well under a very wide range of conditions; on the desert plains where the annual rainfall is stated to be less than 50 in. and the vegetation is scorched for the greater part of the year, and also on the hillsides in poor and rocky soils up to elevations of about 3,500 ft., where the rainfall is probably over 100 in. per annum and the temperature at night falls below 60° F. The tree was never found growing in marshy soil, and it appeared to thrive best in rather scanty soil amongst granite boulders.

It is stated that hoar frost is experienced at night in some districts of Brazil where Ceara trees occur, and that they will grow equally well in a dry or humid atmosphere provided that the soil is not wet.

Collection of the Rubber in Brazil.—Ceara trees are usually tapped in Brazil for seven to eight weeks during the year, the tapping being sometimes divided into two periods with an interval between. It is stated that in Ceara the tapping is usually conducted during the dry season, which extends from June to November. In Bahia the trees occur in two distinct zones, one of which is hot and dry, whilst the other is more humid. In the dry zone the best time for tapping is said to be between October and April, whereas in the humid zone September to January is the most favourable period.

The tapping is performed in a number of ways, of which the following are the most important:

(1) The soil is removed from the base of the tree so as to expose the roots, and incisions are then made on the roots and on the lower portion of the stem. In some cases only small incisions are made, it being stated that the latex flows better from small than from large cuts, but in others large V incisions are used. The hole in the soil made in exposing the roots serves to collect the latex, and is frequently lined with clay in order to prevent

the contamination of the rubber with earthy impurities. The tapping is usually performed every morning, and the latex from the successive tappings is allowed to accumulate in the hole where it slowly coagulates. At intervals the flat cake of rubber which is formed in the hole is removed, washed, pressed, and dried.

Sometimes the coagulation of the latex is accelerated by placing water or a solution of salt or alum in the hole before tapping the tree. In other cases the latex is collected in tin or clay cups and is afterwards coagulated by one of the methods just mentioned, or by a smoking process similar to that employed in the preparation of Para rubber.

(2) The trunk of the tree is tapped by first stripping off the outer bark and then making a series of incisions by means of a small axe or a knife. The latex which exudes either coagulates on the stem, or, if very fluid, runs down to the base of the tree and coagulates on the ground or on leaves placed to receive it. The rubber obtained by this method is in the form of scrap, and if coagulated on the ground it is liable to be contaminated with soil.

Much of the Ceara rubber prepared in Brazil from the wild trees is of inferior quality on account of the careless methods of preparation employed.

No trustworthy estimate is available as to the average annual yield of rubber from wild Ceara trees. It has been stated to be as much as 1 to 3 lb. per annum, whilst, on the other hand, the average for several seasons, good and bad, has been placed at about 4 oz. per tree.

Cultivation of the Ceara Tree.—The introduction of *Manihot Glaziovii* into countries outside its natural habitat dates from 1876, when Cross brought to Kew a number of the living plants and a quantity of the seed which he had collected in Ceara. Plants were raised at Kew from the seed thus obtained and were distributed during the next two years to the various botanic stations in the Colonies for trial. In most places the plants grew exceedingly well and it was soon found that the Ceara tree could be readily cultivated, as it is very hardy, a quick grower, and capable of adapting itself to very varied conditions of climate and soil. The trees produce seed freely at an early age, and as the seeds retain their

vitality for long periods the propagation of the plant is rendered easy. As a result of these favourable features large numbers of the trees were planted in various countries, particularly in Ceylon, and high hopes were entertained as to the probable value of cultivated Ceara trees as a source of rubber. The results of tapping trials were, however, uniformly disappointing, the amount of rubber obtained being small, and planters gradually lost interest in the trees, which, although growing well, would apparently not furnish a remunerative yield of rubber.

More recently, however, the Ceara tree has again come into prominence for cultivation purposes in certain countries, as it can be grown in dry situations where other rubber trees will not thrive, and, with the introduction of methods of tapping suited to its peculiarities, it has been found that remunerative yields of rubber can be obtained. Large numbers of the trees are at present under cultivation in Brazil, East Africa, Southern India, and other countries, and are furnishing rubber of excellent quality, which realises very good prices in the market.

Climatic Conditions and Soil.—The conditions under which Ceara trees are found growing in Brazil have been already described, and reference may now be made to the behaviour of the trees under cultivation in other parts of the tropics.

Ceara trees can be grown successfully in a moderately dry climate with a rainfall of about 40 in. per annum, but they will also do well in a humid atmosphere, with a rainfall of 100 in. or more, provided that the soil is not permanently wet. This latter point is of considerable importance in connection with the cultivation of Ceara trees, which will grow upon almost any soil except a wet one. The trees do well in favourable situations in countries which have a hot dry season of four or five months' duration and they also withstand considerable variations in temperature. It is these features which render the Ceara tree of special value for cultivation in dry districts such as those of East Africa.

In Ceylon the Ceara tree grows very freely, almost like a weed, on all kinds of soil up to elevations of 3,000 ft. and under rainfalls of 30 to 200 in. per annum. In Uganda it is being cultivated successfully at elevations

of about 4,000 ft. with an average annual rainfall of 60 in. and a mean temperature of 73° F., the difference between the day and night temperature being about 30° F.

In Nyasaland, Ceara trees do not give satisfactory results if grown on light, sandy soils, with a rainfall of under 40 in. per annum, unless the trees are planted along streams or on alluvial flats near a river where the roots can reach water. A moderately humid climate has been found to be advantageous to the growth of the trees and also to their survival on tapping. In order to obtain remunerative yields of rubber from Ceara trees in Nyasaland they must be grown on rich soil with a heavy rainfall, and these conditions are only obtained in certain districts. The Ceara tree can, therefore, only be cultivated successfully in parts of the Protectorate.

In the East Africa Protectorate, Ceara trees have been principally planted in the coastal districts where the rainfall varies from 45 to 70 in. per annum and the temperature from 70° to 88° F. A well-drained, fairly rich loamy soil, in a somewhat sheltered position is preferred for the plantations.

Manihot Glaziovii has also been introduced into all the British Colonies and Protectorates in West Africa, and except in very wet situations the trees have usually made good growth. Owing, however, to the small yields of rubber which were obtained from the first tappings, little interest has been taken, until recently, in the trees and their possibilities for purposes of cultivation. It is probable that Ceara trees may be worth planting in the drier districts of West Africa.

Formation of Plantations.—In selecting a site for the cultivation of Ceara trees a sheltered position should be chosen if possible, as the trees are liable to be blown down or broken if exposed to strong winds. In some cases the planting of belts of other trees as wind breaks is advisable to protect the plantation.

The land is cleared in the usual manner and parallel lines are laid out at the distance apart which is to be adopted in planting. Holes, 18 in. square and 18 in. deep, are made and filled with surface soil for the reception of the plants.

Ceara trees are generally grown at distances varying from 6 ft. by 6 ft. to 16 ft. by 16 ft. In Brazil the trees are usually planted very closely, about 6 ft. by 6 ft. or 1,000 trees to the acre. In German East Africa 10 ft. by 10 ft. was formerly adopted, giving 435 trees per acre, but wider planting (about 300 trees per acre) is now usual. In the East Africa Protectorate and Nyasaland 12 ft. by 12 ft., giving 300 trees per acre, is customary. On some estates in Nyasaland, however, the trees have been planted 9 ft. by 9 ft., or 540 per acre, and it is stated that if the soil is sufficiently rich to carry such a number of trees the plan is advantageous, as the dense shade which is quickly formed serves not only to protect the soil from exposure to the sun and to check the growth of weeds, but also prevents the bark of the trees from being scorched, and renders it possible to tap further into the dry season than when the trees are more widely spaced. In some cases Ceara trees have been planted in East Africa 6 ft. by 12 ft., or 6 ft. by 6 ft., and the surplus trees tapped to death after two years and cut out.

Manihot Glaziovii is usually propagated from seed, large quantities of which are produced by the trees at an early age. Seed for planting purposes should be carefully selected from trees which give a good yield of latex and are at least three or four years old. It is stated that seed from younger trees does not produce such vigorous plants. The seed is either planted "at stake" in the positions which the trees are to occupy, or it is sown in nurseries and the seedlings transplanted.

The method of sowing the seed at stake, two or three seeds being placed in each hole and the surplus plants removed subsequently, has been adopted largely in Nyasaland and German East Africa, and is said to give very good results if the sowing is done at the proper time, viz. at the beginning of the rains. In Nyasaland it has been found that if the seeds are sown early in the rainy season the plants are sufficiently grown to take care of themselves when the dry season arrives, and do not require watering or shade.

If the plants are to be raised in nurseries, beds are prepared in a sheltered position, but exposed to the sun, and the seeds are sown a few inches apart and about ½ in.

deep. The bed should be watered regularly in order to keep the soil moist.

Germination is frequently slow, especially with fresh seed, and it is sometimes sought to accelerate it by soaking the seed in water; by filing through the hard seed-coat at the narrow end of the seed before sowing; or by placing the seeds in a hot bed and transferring them to the nursery bed as soon as germination has begun. With reference to the first plan, however, a series of experiments made in German East Africa showed that soaking the seed in water for varying periods had no influence on the rate of germination. If the filing method is adopted care must be taken that the embryo of the seed is not damaged; the seed-coat should be only just filed through. It is stated that seed which has been kept for one or two years germinates quite readily and gives good results.

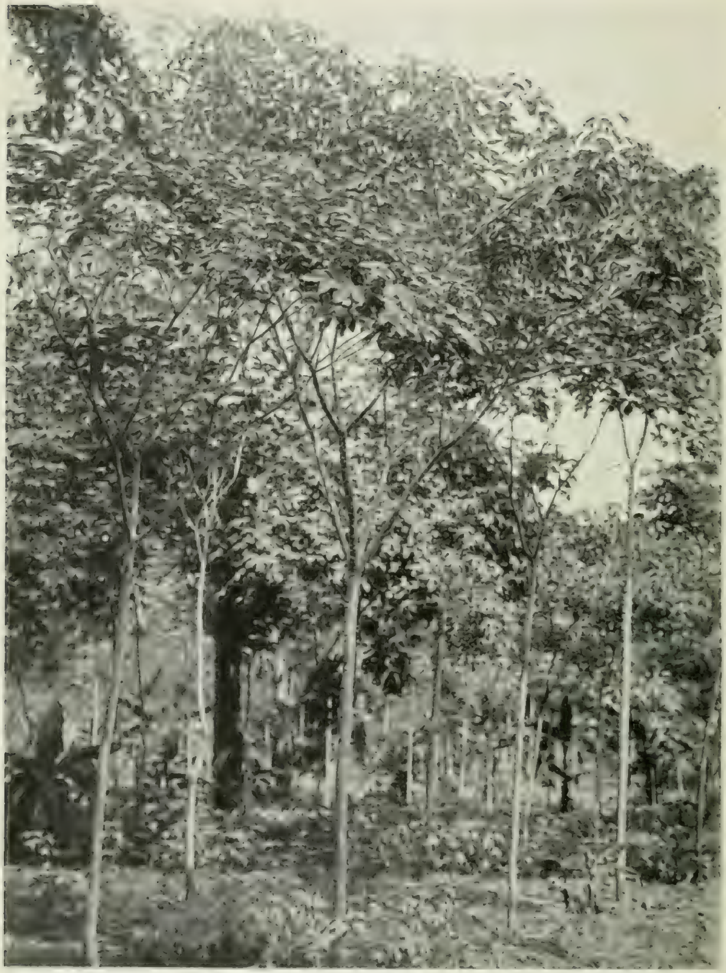
The seedlings are planted out when they are from a few inches to 2 ft. high, and the transplanting should always be done when the ground is moist after rain. Stumping the larger seedlings is not necessary, but is adopted by some planters, the stems being cut back to about 10 in. A plant is placed in each of the prepared holes and the soil pressed firmly round the roots.

The plantation will require weeding for the first two or three years, and during this period catch crops, consisting of cotton, maize, beans, sesame or ground nuts, are sometimes grown between the rows if the trees are planted sufficiently widely. In Nyasaland it is thought that the trees benefit by being thoroughly cultivated up to the fourth year, as a very marked improvement has been observed in the results given by such trees.

In some cases cultivated Ceara trees show a tendency to branch low down, and when this occurs, early pruning is necessary in order to obtain a good erect stem for tapping.

Cost of Establishing Plantations.—The following estimate has been given of the cost of establishing Ceara plantations in the East Africa Protectorate. The expense of clearing will vary with the nature of the land, and the estimate assumes that the site is fairly free from timber.

PLATE VI



From the Collections of the Imperial Institute

CEARA TREES IN THE EAST AFRICA PROTECTORATE

Trees eighteen months old

	Per acre.
Cost of clearing (native labour, etc.)	*Rs.* 15
Holing	5
Rearing plants in nursery and planting out . . .	15
Weeding and cleaning for first three years . . .	30
Sundries (filling in vacancies, etc.)	5
	Rs. 70 = £4 13*s.* 4*d.*

Rate of Growth.—The Ceara tree makes very rapid growth under favourable conditions, and the following particulars will indicate the rate of development in several countries :

Brazil.—Biffen states that one-year-old Ceara trees which he saw at Baturité were 10 to 12 ft. high, and that trees five to six years old and ready for tapping are about 25 ft. high with trunks 8 to 9 in. in diameter.

Uganda.—At the Government Plantation at Kampala twenty Ceara trees planted in November 1909 were found to have an average girth of 16·45 in. at 3 ft. from the ground in November 1911, and 17·32 in. in March 1912. A second group of twenty trees, also planted in November 1909, had an average girth of 15·6 in. in March 1912.

Three eight-year-old trees growing in the Botanic Gardens at Entebbe had an average girth of 30 in., the largest measuring 35 in. and the smallest 25 in.

Many of the three-year-old trees in the Protectorate have attained a girth of over 20 in. at 3 ft. from the ground, whilst the largest eight-year-old tree measured just under 4 ft. in girth. The oldest Ceara trees in Uganda are growing on poor, stony soil, and measured 30 in. in girth when ten years old.

East Africa Protectorate.—It is stated that Ceara trees growing under favourable conditions in the East Africa Protectorate may attain a height of 8 to 10 ft. with a girth of 5 to 6 in. within a year from planting out. Three-year-old trees at Kibwesi were 22 ft. high, the trunk measuring 10 ft., and 19 in. in girth at 3 ft. from the

ground. Equally good growth is said to have been obtained at several places in the coast belt.

NYASALAND.—The following measurements have been recorded for Ceara trees growing in the West Nyasa district, which is one of the best in the Protectorate for rubber cultivation: 101 trees, 3½ years old and planted 15 ft. by 15 ft., had an average girth of 19·43 in. at 3 ft. from the ground, the largest measuring 30 in. and the smallest 13 in.; 105 trees, 1½ year old and planted 10 ft. by 10 ft., had an average girth of 10·66 in., the largest measuring 17 in. and the smallest 8 in.

Trees raised from seed planted at stake on good deep red soil attained a height of 6 to 8 ft. within eight months after sowing, and were 16 ft. high when eighteen months old.

SOUTHERN NIGERIA.—Two ten-year-old trees growing at Calabar had an average girth of 44 in., whilst seven eight-year-old trees at the same place measured 31 in. in average girth. At Onitsha six seven-year-old trees had an average girth of 33 in.

Methods of Tapping.—The Ceara tree is more difficult to tap successfully than the Para tree, and most of the early tapping experiments, which were made by the methods then employed for the latter tree, gave unfavourable results both on account of the low yield of rubber and of the liability of killing the trees. The peculiarities of the Ceara tree as regards its behaviour on tapping are better understood now, and methods have been devised which obviate the risk of damaging the trees whilst furnishing remunerative yields of rubber. It is stated, however, that in Ceylon no system of tapping has yet been found which is not liable to kill the trees, especially in districts where the rainfall does not exceed 50 in., but that owing to the very rapid growth of the trees this is a matter of little importance, as the place of any trees destroyed is speedily filled.

The method of tapping to be employed for Ceara trees depends very largely on the climatic conditions of the country, particularly as regards the humidity. In dry countries the latex will not flow freely when incisions are made in the bark, but coagulates on the stem, and the rubber is obtained in the form of scrap. In this case the tapping is conducted by making a series of small incisions

with a knife or a pricker, no bark being removed. In wetter districts, however, the trees can be tapped by the herringbone or some similar excision system, the latex being collected in bulk and subsequently coagulated. Thus, for example, in German East Africa the incision method can alone be used in the northern districts, whereas herringbone tapping can be adopted in the south. In some districts of Nyasaland where dry winds occur during the tapping season, an excision system of tapping has been found unsatisfactory, as the bark does not heal under such conditions, but dies back at the edges of the cut and leaves the wood.

Whichever of these two methods is to be employed, it is customary, except in the case of very young trees tapped by the incision system, to strip off the outer layer of bark from the portion of the stem which is to be tapped. This outer bark, although thin, is exceedingly hard and very quickly takes the edge from the tapping tool; moreover, it becomes detached from the inner bark in places, and some latex is liable to be lost by running down between the two layers. The outer bark can be very easily stripped from the stem after making two vertical cuts at the sides of the portion of bark to be tapped. In this connection, however, it must be stated that some authorities consider the removal of the outer bark to be unnecessary and likely to be detrimental to the tree.

The incision system of tapping most commonly used for Ceara trees is known as the "Lewa" method, from the name of the estate in German East Africa where it was first adopted, and is carried out as follows:

The outer bark is removed from one-fourth or more of the circumference of the stem to a height of 6 ft., and the stripped surface is then moistened with the acid juice of a citrus fruit—limes, oranges, or lemons—in order to facilitate the coagulation of the latex. Dilute acetic acid (2 per cent.) or a mixture of acetic and carbolic acids, or a weak solution of calcium chloride, is also employed for the purpose, as well as an infusion of the pulp of baobab fruits and the juice of sisal leaves. A large number of small horizontal incisions are then made by stabbing the bark with the end of a thin-bladed knife having a straight cutting edge, care being taken that the cuts do

not penetrate too deeply. It is stated that a chisel-edged tool is not so suitable for the purpose, as the cuts do not heal so quickly as those made with a thin-bladed knife. The incisions are usually made in vertical rows 2 to 3 in. apart. A number of different forms of thin-bladed prickers are also employed for making the incisions in place of the knife.

The latex exudes from the cuts, and in contact with the acid solution it quickly coagulates on the stem. The rubber thus formed can be collected after a short interval, the strips being either wound into balls or kept in the form of scrap, which may be subsequently converted into crêpe by means of a washing machine. In some cases the rubber is collected by winding the strips on a wooden roller, and then, after cutting the covering of rubber along one side, it is stripped off and converted into a flat cake by pressure.

When the Lewa method is employed the trees may be tapped at frequent intervals, and the following plan is one of the systems which has been adopted in East Africa. One half of the tree is tapped every alternate day for two months and the tree is then allowed to rest for one month ; the second half of the tree is then tapped every alternate day for two months and the tree is again allowed to rest for a month ; the first half is then retapped as before, and so on. Strips of untapped bark from 3 to 4 in. wide are left between the two tapping areas.

Ceara trees can be lightly tapped by the Lewa method at a very early age, commencing about the end of the second year, and it has been claimed that trees thus treated give better yields of latex subsequently than if they are left untapped until four or five years old.

In situations where the latex of Ceara trees flows more freely, the herringbone system of tapping may be employed after the removal of the outer bark. Half of the tree is usually tapped at a time to a height of 6 ft., the lateral incisions being made 1 ft. apart, and the single or double herringbone is used according to the size of the tree. The flow of the latex is sometimes facilitated by allowing a slow stream of water containing a little ammonia to run down the incisions from drip-tins ; the latex may also be prevented from coagulating in the collecting cups by the addition of a little ammonia.

Experiments have been made in Nyasaland and Uganda to determine the effect of reopening the incisions by means of a parer or a parer and pricker, as in the case of Para trees, and very promising results have been obtained (see pp. 151–4). Great care is, however, required in tapping by this method to avoid injuring the cambium, as the bark of Ceara trees is thinner than that of Para trees.

Johnson has introduced a modified form of herringbone tapping based on his experiments with Ceara trees. The outer bark is removed from one half of the tree to a height of 6 ft. and a vertical channel is cut at one side of the stripped area; six transverse cuts, 1 ft. apart, and the lowest 1 ft. from the ground, are then made over the half of the trunk and the latex is collected. Four days later six more lateral cuts are made between the first series; after four more days a third series of six incisions is made in the alternate spaces between the first two series; and finally, four days later, six further cuts are made in the remaining spaces. The tree is then allowed to rest until the wounds have healed, when the opposite side of the tree is treated in the same way, the two halves being thus tapped alternately. Some results obtained by this method are given on p. 155.

Long vertical cuts have also been used successfully in Nyasaland for tapping Ceara trees, and this method is stated to have given the best results in some experiments conducted in Hawaii. The procedure adopted in the latter case was to make a number of very shallow vertical incisions 4 to 5 in. apart in the bark; the next day the initial cuts were deepened so as to liberate the latex, and then the incisions were reopened, always on the same side, every day during the tapping period. It is stated that very good yields of latex were obtained by tapping in this way, and that the bark healed rapidly from the side of the cut which was not reopened.

In Brazil cultivated Ceara trees are tapped by the same methods as those employed for the wild trees (see p. 139).

Coagulation of the Latex.—The latex of the Ceara tree is very easily coagulated. It is first strained to remove all mechanical impurities and is then diluted with water and allowed to stand for a few hours, or overnight, until complete coagulation has taken place. Sometimes the

diluted latex is rendered just acid by the addition of acetic acid, but this is not necessary unless ammonia has been used in collecting it. This method is very convenient for the preparation of the rubber in biscuit form. In order to obtain the best results the latex should be well diluted with water and the rubber obtained should be thoroughly washed.

Yield of Rubber.—Considerable variation has been observed in the yield of rubber furnished by cultivated Ceara trees of the same age growing in the same locality, and in order to obtain a trustworthy estimate for the yield of a plantation it is necessary to take the average of a considerable number of trees. Thus, for example, in East Africa, single trees nine to ten years old are stated to have yielded as much as 10 to 12 lb. of dry rubber in a year, whereas 1 lb. per annum is a high average yield from trees of this age, and the yield from plantations of trees three years old and upwards is about 4 oz. of dry rubber per tree annually. In the following account a summary is given of the yields obtained in different countries:

BRAZIL.—The average yield of rubber from cultivated Ceara trees in Brazil has been given as 300 kilograms per hectare, and as the trees are usually planted about 2,500 to the hectare, this is equivalent to a little more than 4 oz. per tree per annum.

CEYLON.—The superintendent of an estate upon which a large number of Ceara trees are growing has expressed the opinion that ½ to ¾ lb. of dry rubber per tree is as much as the trees will yield annually, if they are to be tapped for long periods and retain their vitality. This estate has exported Ceara rubber since 1886.

EAST AFRICA.—In German East Africa there are about 60,000 acres of Ceara trees under cultivation, and Professor Zimmermann, of the Biologisch Landwirtschaftlichen Institut at Amani has published the following figures as representing the average yields of dry rubber from trees of different ages:

Age of trees. Years.	Kilograms of rubber per hectare.	lb. of rubber per acre.
4	50	44
5	100	88
6	150	132

Age of trees. Years.	Kilograms of rubber per hectare.	lb. of rubber per acre.
7	200	176
8	200	176

The average number of trees per hectare is now about 800, equal to 320 per acre.

It is anticipated that the Ceara trees in the East Africa Protectorate will furnish similar yields to those obtained in German East Africa.

Nyasaland.—Except in certain favourable districts Ceara trees can only be tapped in Nyasaland during about six months of the year. In the greater part of the Protectorate there is practically no rain for six months, and tapping is only possible during dry periods in the wet season and at the beginning of the dry season. If the tapping is continued too far into the dry season it has been found that the incisions do not heal and that the trees suffer in consequence. From the results of tappings carried out on a number of estates it is thought that about 3 oz. of dry rubber in six months may be considered as a good average yield from four-year-old Ceara trees in Nyasaland.

On an estate near Blantyre 443 four-year-old trees, planted 15 ft. by 9 ft. and 12 ft. by 9 ft., were tapped twice within a month. 170 of the trees were less than 12 in. in girth at 3 ft. from the ground, and these yielded 42 oz. of dry rubber, or approximately ¼ oz. each. The remaining 273 trees, which varied from 12 to 19 in. in girth, yielded 356 oz. of dry rubber, or approximately 1⅓ oz. per tree from the two tappings within a month. The cost of collection is stated to have been 4*d.* per lb. of dry rubber.

On another estate at Mlanje a number of two-and-a-half-year-old trees, planted 9 ft. by 9 ft., were tapped on alternate days and during a period of several weeks the average yield of rubber per tree at each tapping was 0·09 oz. If this yield is continued it is probable that 5 or 6 oz. of dry rubber may be obtained per tree in six months' tapping.

On the Chitalika estate eighteen Ceara trees were tapped by the herringbone system, and the incisions were reopened every alternate day by paring. The trees were tapped for a month, then allowed to rest for about a month, and so on. During five tapping periods.

extending over ten months, the following yields of wet rubber were obtained:

				Yield of wet rubber. oz.
1st tapping period,	12 tappings	(Nov.–Dec.)	.	$56\frac{1}{4}$
2nd ,, ,,	13 ,,	(Jan.–Feb.)	.	$40\frac{3}{4}$
3rd ,, ,,	14 ,,	(Apr.–May)	.	$83\frac{3}{8}$
4th ,, ,,	10 ,,	(June–July)	.	$55\frac{1}{4}$
5th ,, ,,	13 ,,	(Aug.–Sept.)	.	$44\frac{1}{2}$
	62 tappings	. .	.	$280\frac{1}{8}$

It was stated that the wet rubber lost approximately half its weight on drying, so that the total yield of dry rubber was about 140 oz. or nearly 8 oz. per tree in the ten months.

It has been proved that in Nyasaland, Ceara trees can be tapped when from two to three years old without injurious effects, and the rubber obtained from such trees is of good quality and realises a satisfactory price in the market.

UGANDA.—A number of tapping experiments on Ceara trees growing in the Botanic Gardens at Entebbe and on an adjacent plantation were recently conducted by Fyffe and have given very interesting results. The trees were tapped by the half-herringbone system, and the incisions were reopened every alternate day by paring and pricking, as in the case of Para trees. Much better yields of rubber were obtained by this method than by the Lewa process, and it was stated that trees which had been tapped more or less regularly by this system for thirteen months showed no ill effects except in a few cases where the cuts had been made too deeply, owing to the inexperience of the tappers. None of the trees was killed by the treatment.

The following account gives a summary of the experiments:

(1) In the first experiment three eight-year-old trees having an average girth of 2 ft. 6 in. were tapped by the herringbone system, the dry outer bark having been first removed. The trees were retapped every evening between 5.30 and 6.30 p.m. by paring off a thin shaving

from the lower edge of each cut and then employing a pricker; the use of the pricker was, however, abandoned during the experiment and the latex liberated simply by paring the edges of the cuts. The trees, which were tapped fourteen times, yielded practically the same quantity of latex from the first eleven tappings; on the twelfth day the flow of latex was rather sluggish and the yield decreased very appreciably on the thirteenth and fourteenth days. Tapping was therefore abandoned after the fourteenth day.

The total yield of dry rubber was 2 lb., equal to a yield of 10·66 oz. from each tree in fourteen daily tappings.

(2) A second trial was made with four trees of various sizes but having an average girth of 19½ in. The trees were tapped ten times on alternate days, the herringbone system being employed and the edges of the cuts being reopened by paring.

The total yield of dry rubber obtained was 15 oz., equal to a yield of 3·75 oz. per tree from ten tappings on alternate days.

(3) In a third experiment three Ceara trees approximately eight years old were used; they were growing on poor, stony soil, and had an average girth of 30 in. Tapping was done by the half-herringbone system to a height of 4½ ft. and was continued every alternate day for ten weeks, the parer and pricker being used.

The total yield of dry rubber was 57 oz., equal to 19 oz. per tree in ten weeks.

The wound response was stated to have been good throughout the experiment, and, except in the case of one tree which was tapped a little too deeply, new bark formed rapidly at the conclusion of the experiment.

(4) A further experiment was conducted on a plantation of Ceara trees at Entebbe. Twenty trees approximately two and three-quarter years old were employed; the average girth of the trees was 19 in. at 3 ft. from the ground, the largest being 26 in. and the smallest 16 in. The tapping was done by the half-herringbone system, using half the bark to a height of 3½ ft., and was repeated every alternate evening between 5.30 and 6.30 p.m. for one month, each tree being tapped fifteen times by paring and pricking.

The total yield of dry rubber was 2 lb. 5½ oz., of which

1 lb. 14½ oz. was biscuit rubber. The yield per tree was therefore 1·88 oz. for fifteen tappings extending over one month, which must be regarded as very satisfactory considering the age of the trees. It was noticed that some of the trees gave much higher yields of rubber than others.

The results obtained with this paring and pricking process are very promising, but further experiments extending over a longer period will be required before a final opinion can be formed. Fyffe states that in re-tapping a thin paring should be cut from the lower edge of the incision and the latex liberated with a very fine pricker. The tapping is not detrimental to the trees if it is carefully performed, none of those operated upon having died, and the bark is renewed rapidly. The advantage of the method is that it gives a larger yield of rubber, which moreover can be easily prepared in biscuit form instead of being obtained as scrap.

(5) This method of paring and pricking was subsequently tried with young Ceara trees at the Government Plantation at Kampala. Half-herringbone incisions extending over half the circumference were made to a height of 4 or 5 ft. and the cuts were reopened on alternate days. The following table summarises the results of the experiments:

No. of trees.	Date of planting.	Period of tapping.	Average girth at 3 ft.	No. of tappings.	Total yield of dry rubber.
					oz.
A. 20 trees	Nov. 1909	(1) Nov. 15 to Dec. 31, 1911	16·45	20	10·0
		(2) March 1912	17·32	14	11·5
B. 20 trees	Nov. 1909	March 1912	15·60	12	6·0

The tapped trees showed no signs of injury and after the experiments they grew quite as vigorously as trees which had not been tapped.

Portuguese East Africa.—Tapping experiments on Ceara trees growing in Portuguese East Africa were conducted by Johnson (see *Bulletin of the Imperial Institute*, vol. v. 1907, p. 401).

One hundred and ten trees, seven to nine years old, were selected for the purpose, and were found to have an average girth of 29·6 in., the largest measuring 44·5 in.

and the smallest 23·6 in. The trees were divided into thirteen groups, which were tapped in different ways by the spiral, herringbone, and pricking systems, the incisions in the first two methods being reopened every second or fourth day. The experiments lasted about one month, and the number of tappings varied from six to thirteen in the different groups. The average yield of dry rubber per tree was 112·5 grams (3·97 oz.), made up of biscuit and scrap in nearly equal proportions.

SOUTHERN NIGERIA.—Tapping experiments have been conducted on Ceara trees growing at Calabar and Onitsha in Southern Nigeria. The trees were tapped eight times during a period of two and a half months by Johnson's method (see p. 149), and furnished the following results:

District.	No. of trees.	Age.	Average girth at 3 ft.	Number of tappings.	Average yield of dry rubber per tree.	Average yield of dry rubber per tree per tapping.
		Years.	in.		oz.	oz.
Calabar .	2	10	44·1	8	8	1
,, .	7	8	31·1	8	3·57	0·45
Onitsha .	6	7	33	8	0·92	0·12

The yield from the trees at Calabar was very good, amounting to 8 oz. and 3·57 oz. per tree in the two groups for two and a half months' tapping. The trees at Onitsha gave much less rubber, possibly owing to the facts that they have been neglected and that the rainfall at that place is much less than at Calabar.

BELGIAN CONGO.—The following table summarises the results of a number of tapping experiments made on Ceara trees in the Belgian Congo:

District.	No. of trees tapped.	Age.	Tapping period.	Yield of dry rubber per tree.	
		Years.	Days.	lb.	oz.
Borna (Lower Congo) . .	4	6	17	0	4
,, ,, . .	23	—	21	0	8
,, ,, . .	1	10–12	24	2	8
Kalamu (Lower Congo) .	129	6	31	0	3½
Kitobola (Lower Congo) .	40	—	10	0	7
,, ,, . .	200	8	25	0	3¼
,, ,, . .	160	8	1	0	3⅓
Romée (Stanleyville) . .	1	8	9	0	10½
,, ,, . .	1	7	12	0	9⅓
,, ,, . .	1	6	10	0	4½

Composition of Ceara Rubber.—As a general rule the latex of the Ceara tree contains considerable quantities of resin, protein, and mineral matter, and in consequence the rubber obtained by the coagulation of the latex on the stem, and collected in the form of scrap or balls, is usually characterised by the presence of large percentages of these constituents. Even if the rubber is carefully prepared in biscuits, sheet, or crêpe it generally contains much larger amounts of resin, protein, and ash than plantation Para. The rubber, however, possesses excellent physical properties, and the best qualities realise prices equal to those of fine plantation Para.

The following analyses made at the Imperial Institute show the composition of a number of samples of Ceara rubber from different countries:

Country.	Description of rubber.	Composition of dry washed rubber.			
		Caoutchouc.	Resin.	Protein.	Ash.
		Per cent.	Per cent.	Per cent.	Per cent.
Southern India . .	Biscuit	82·5	6·4	9·8	1·3
,, ,, . .	Scrap	76·3	4·7	16·6	2·4
Ceylon . . .	Sheet	92·2	3·1	3·4	1·3
Uganda . . .	Crêpe	88·7	6·2	4·3	0·8
,, . . .	Biscuit	89·3	5·9	3·7	1·1
,, . . .	,,	84·0	5·0	9·3	1·7
East Africa Protectorate	Ball from 1½-year-old trees	69·3	10·1	16·2	4·4
Sudan . . .	Biscuit	81·9	5·9	10·0	2·2
Nyasaland . . .	Biscuit	86·1	6·8	6·2	0·9
,, . . .	Ball from 2-year-old trees	78·6	10·8	8·4	2·2
Portuguese East Africa	Biscuit	84·4	5·8	8·3	1·5
,, ,,	,,	82·8	5·5	9·4	2·3
,, ,,	,,	85·6	6·3	6·2	1·9
,, ,,	,,	84·6	6·8	7·0	1·6
Gold Coast . . .	Scrap	70·9	4·6	21·3	3·2
Southern Nigeria . .	Balls	84·1	7·8	6·5	1·6

For comparison with these figures the analyses made by Bamber of the prize specimens of Ceara rubber at the Ceylon Rubber Exhibition in 1906 may be quoted:

Description of rubber.	Moisture.	Caoutchouc.	Resin.	Protein.	Ash.
Ceara biscuits :	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Rangboddo * .	0·70	92·58	3·80	2·12	0·80
North Matale .	3·10	87·97	1·40	6·13	1·40
Ceara Sheet :					
Kondesalle † .	1·58	86·14	5·74	5·06	1·48

The New Species of Manihot.—A short description may now be given of the three new rubber-yielding species of Manihot, *M. dichotoma*, *M. heptaphylla*, and *M. piauhyensis*, which were discovered recently by Ule in Brazil.

Manihot dichotoma, Ule.—*M. dichotoma* is a small tree, 16 to 40 ft. in height, which usually has a pale bark and develops a densely branched crown. The leaves are membranous, divided into three to five segments (peltate only in the seedlings), and are much smaller than those of *M. Glaziovii*. It differs also from the latter tree in having large ellipsoidal seeds.

It occurs in the south-eastern portion of the State of Bahia, between the Rio Paraguassu and the Rio das Contas. The tree is generally known as the Jequié Maniçoba from the town of Jequié, which is the centre of the rubber industry in the district. It appears to thrive best on red loamy soil, but it is also found more rarely on sandy soil.

The seeds of this species are stated to germinate very readily.

Manihot heptaphylla, Ule.—*M. heptaphylla* is a much smaller tree than *M. dichotoma*, only attaining a height of from 10 to 25 ft.; it has a short stem which is covered with blackish-brown bark and the twigs are purple. The leaves are oblanceolate, dark green, and usually divided into seven segments. The seeds resemble those of *M. Glaziovii* in shape, but they are rather larger and lighter in colour.

This species is found in the State of Bahia on the right bank of the Rio San Francisco, especially in the mountainous districts of the Serra do Encaibro, Serra do Tombador, and Serra do Assurua.

* From trees 20 years old at altitude of over 3,000 ft.
† From 300 trees, 8 to 20 years old, at altitude of 1,500 ft.

Manihot piauhyensis, Ule.—*M. piauhyensis* is of similar habit to *M. heptaphylla*, but is rather smaller, being only from 6 to 16 ft. in height. The leaves are bright green, broadly obovate or oblong-obovate, and are divided into five segments. The fruits are distinguished from those of *M. heptaphylla* by being winged at the corners, but the seeds are very similar to those of the latter species.

M. piauhyensis is widely distributed in the south-eastern portion of the State of Piauhy along the Bahia boundary, where it occurs on the lower sandstone mountain ranges.

Collection of the Rubber.—In Brazil the rubber of *M. dichotoma* is obtained by making incisions in the bark of the stem and collecting the latex in cups; the latex very quickly coagulates spontaneously. *M. heptaphylla* and *M. piauhyensis* are usually tapped at the base of the stem only, by the method employed for *M. Glaziovii*; the latex is allowed to run into a hole made in the ground and to remain there until coagulation has occurred. It is stated that the amount of rubber collected annually in Brazil from the three species during recent years is approximately as follows: 400 to 500 metric tons from *M. dichotoma*, 500 tons from *M. heptaphylla*, and at least 600 tons from *M. piauhyensis*. If these figures can be accepted as correct, it would appear that half or more of the total Maniçoba rubber exported from Brazil is derived from the three new species.

Value for Cultivation.—It is stated that the yield of rubber obtained from *M. dichotoma*, *M. heptaphylla*, and *M. piauhyensis* is usually greater than that furnished by *M. Glaziovii*, and Ule expressed the opinion that wherever the conditions are suitable, the new species should be cultivated in preference to the Ceara tree. *M. dichotoma* is regarded as most suitable for good, loamy soils, and the other two species for light, sandy soils.

Plantations of the trees have been formed in Brazil, the seeds being usually planted "at stake" about 2 metres apart, giving approximately 1,000 trees per acre. No definite figures as to the actual results obtained by tapping the cultivated trees on a large scale are, however, available. According to published statements *M. dichotoma* will yield from 100 to 200 grams of rubber per tree annually, whilst the amount obtainable from the other

two species is put at 500 to 1,000 grams per annum. The rubber of *M. dichotoma* is, however, of better quality than that of the other species.

Seeds and plants of the three species have been distributed by Kew to almost all the tropical British Colonies, and the trees are at present undergoing trials, in comparison with the Ceara tree, in many tropical countries. It is, however, too early yet to pronounce any opinion as to the respective merits of the different species.

In Ceylon *M. dichotoma* is being experimentally cultivated at the Peradeniya Experiment Station, three acres having been planted with the trees at varying distances apart, 20 by 20 ft., 12 by 12 ft., 8 by 8 ft., and 6 by 6 ft. The results so far are very promising, as the species appears to thrive better than *M. Glaziovii*. The chief defect is the extreme brittleness of the tree, the tops being very liable to damage by wind, and belts of other trees would therefore be required as "wind-breaks" in cultivating the tree.

Recently a number of the *M. dichotoma* trees in Ceylon were tapped for the first time and the rubber obtained was examined at the Imperial Institute with the following results:

	Per cent.
Moisture	0·5
Caoutchouc	84·6
Resin	4·9
Protein	5·7
Insoluble matter	4·3
Ash	2·9

The insoluble matter consisted of fine particles distributed through the sample, and owing to the soft character of the rubber it was found impossible to eliminate the impurity by washing. The rubber is of very fair quality so far as composition is concerned, and the physical properties may improve as the trees increase in age.

CHAPTER XI

THE AFRICAN RUBBER TREE, *FUNTUMIA ELASTICA*, STAPF (*KICKXIA ELASTICA*, PREUSS)

Kickxia and Funtumia.—The African rubber tree belongs to the natural order Apocynaceae and was first described as *Kickxia elastica* in 1899 by Preuss from specimens collected near Malinde in the Cameroons. Two other allied species, *Kickxia africana*, Benth., and *Kickxia latifolia*, Stapf, had been previously recorded from Africa, and until Preuss's discovery, *Kickxia africana* had been regarded as the rubber-yielding tree. Preuss proved, however, that *Kickxia africana* does not yield rubber but only a resinous product, and that the rubber tree was a distinct species.

Prior to the discovery of these African species of Kickxia the genus comprised only four species, which were restricted to Malaya, and it therefore appeared that the two groups of Kickxias were widely separated in their geographical distribution. Stapf, however, made a detailed study of the African and Asiatic species, and showed that the two groups exhibit marked differences in their morphological characters which are sufficient to justify their recognition as distinct genera. He therefore retained the name Kickxia for the Malayan group, and placed the African species in a new genus, for which he proposed the name Funtumia, from Funtum or O'Funtum, one of the vernacular names in West Africa for the rubber-yielding species. The African rubber tree is therefore known either as *Funtumia elastica*, Stapf, or *Kickxia elastica*, Preuss.

Botanical Characters.—*Funtumia elastica* is a large forest tree, sometimes attaining a height of 100 ft., with an erect tapering cylindrical trunk which is usually covered with a mottled grey bark. The leaves are oppo-

Funtumia elastica, STAPF, THE AFRICAN RUBBER TREE

A. Flowering shoot B. Under surface of leaves C. A single follicle of the fruit
D. Seeds with attached silky hairs

site, oblong or lanceolate-oblong, with acuminate apex, 5 to 10 in. long and 1½ to 4½ in. broad, undulate, and quite free from hairs. On the under surface of the leaves, in the angles made by the side veins with the midrib, minute pits known as "acarodomitia" occur. The flowers are white or yellowish, conical in the bud and salver-shaped when open; they are borne in many-flowered, dense, axillary cymes. The fruit consists of two broad follicles joined at the base and obtuse or rotund at the apex. The seeds are spindle-shaped and are furnished with a plumose basal awn of silky hairs. (See Plate VII.)

The presence of the minute pits on the under surface of the leaves is a very useful character for distinguishing *Funtumia elastica* from the two allied species in the absence of flowers or fruits. It cannot, however, be absolutely relied upon, as leaves of *Funtumia africana* are occasionally found which exhibit the same character.

The allied species *Funtumia africana*, which does not yield rubber, is widely distributed throughout West Africa in the same situations as *Funtumia elastica*. It is distinguished from the latter by its much narrower follicles, by its longer cylindrical flower-buds, and usually by the absence of pits on the under surface of the leaves. The third species, *Funtumia latifolia*, occurs in the Congo district and in Uganda; it is of no value as a source of rubber.

Distribution.—*Funtumia elastica* is very widely distributed throughout Central Africa. Its western limit is Sierra Leone, and it extends thence right across the continent into the East Africa Protectorate, and to the south of this line into the Belgian Congo. The countries from which it has been recorded are: Sierra Leone, Liberia, the French Ivory Coast, Togoland, Dahomey, Northern and Southern Nigeria, the Cameroons, the French Congo, the Belgian Congo, Uganda, and the East Africa Protectorate.

With reference to its occurrence in the British Colonies and Protectorates in Africa, the tree is especially abundant in the Gold Coast (principally in Ashanti), in the Western and Central Provinces of Southern Nigeria, and in Uganda. It also occurs, but not so freely, in the southern portion of Northern Nigeria, in the eastern

districts of the Sierra Leone Protectorate, and in the East Africa Protectorate.

Until 1903 it was thought that *Funtumia elastica* was restricted to western Africa, but in that year the tree was discovered in Uganda by Dawe in the Mabira Forest near the Victoria Nyanza, and in 1911 it was also found by Battiscombe in the East Africa Protectorate in the forests bordering the Victoria Nyanza.

Climatic Conditions.—*Funtumia elastica* is essentially a forest tree, and in West Africa it occurs naturally in both the "rain forests" (the moist tropical evergreen forests) and in the "monsoon forests" (the mixed deciduous forests). It is, however, most abundant in the monsoon forests, which have alternating wet and dry seasons and the trees of which are more or less leafless during the dry season. The conditions of rainfall under which the Funtumia tree occurs vary considerably in different countries. In West Africa it is stated to do best in districts which have a rainfall of 60 to 100 in. per annum; in the Belgian Congo it appears to thrive in districts where the rainfall averages from 48 to 60 in. and where the dry season sometimes lasts for six months; whilst in Uganda the tree grows in the drier forests which have an annual rainfall of about 58 in.

In West Africa *Funtumia elastica* is found principally at low elevations, but in the Cameroons it occurs up to altitudes of 1,500 to 2,000 ft., and in Uganda up to 4,000 or 5,000 ft., whilst in the East Africa Protectorate it is found between 5,000 and 6,000 ft. above sea-level.

Soil.—The Funtumia tree appears to grow best on red clay soils and it is seldom found on sandy soils or on swampy land. The following analysis by Schidrowitz shows the composition of a sample of red soil from the Chagwe Forest in Uganda, which was collected by Christy as representative of the soil upon which *Funtumia elastica* is usually found growing wild:

PHYSICAL ANALYSIS

	Per cent.
Fine soil passing 90 mesh . . .	9·71
Fine soil passing 60 mesh . . .	6·86
Medium soil passing 30 mesh . .	17·14
Coarse material and stones . . .	66·29

CHEMICAL ANALYSIS

	Per cent.
Moisture	2·66
Organic matter and combined water .	14·42
Nitrogen	0·317
Nitrogen as ammonia	0·385
Total phosphoric acid	0·15
Phosphoric acid soluble in citric acid .	0·012
Potash	0·19
Sand and silicates (insoluble matter) .	64·92
Lime, iron, alumina, etc. (by difference)	17·66
Iron	Large amount
Acidity	Strongly acid
Carbonates	Absent

Native Methods of Tapping.—In many parts of West Africa it was formerly customary to fell the Funtumia trees in order to obtain the rubber, and this practice still persists in certain districts of the Ivory Coast and Sierra Leone. Sometimes after felling the tree the natives make a large number of incisions in the bark a short distance apart and encircling the trunk. The latex thus obtained is collected in vessels and subsequently coagulated.

Another method adopted in some parts of Sierra Leone is to fell the tree and then to cover the trunk with dry grass, which is set on fire. The heat from the burning grass suffices to coagulate the latex in the bark, which is then stripped off and the rubber extracted from it by beating in the manner described later for Landolphia bark (see p. 195).

As a general rule, however, the natives collect the latex of *Funtumia elastica* by tapping the standing trees, a gouge of native manufacture being used for making the incisions. The double-herringbone system is usually employed, and the incisions are carried up the trunk as high as the first branches and sometimes even higher. In many cases as much as 60 ft. of the trunk is tapped, the collector climbing the tree for the purpose by means of slings. The lateral incisions are made from 6 to 12 in. apart, and they frequently extend right round the trunk or even overlap. The collector cuts the vertical channel as he ascends the trunk and the lateral channels as he

descends. A piece of metal or wood or a portion of a leaf is inserted at the base of the vertical channel and serves to direct the latex into a calabash or other receptacle; sometimes a lip of clay is formed for this purpose. The trees are retapped after an interval of some months, when the first incisions have healed. The second vertical channel is made alongside the first, or on the opposite side of the trunk, and the lateral incisions frequently cross those of the previous tapping.

The principal objections to the native method of tapping are (1) the excessive height to which the incisions are carried, (2) the extent to which the lateral incisions encircle the stem, (3) the depth of the cuts which usually expose the wood, and (4) the frequency of the tappings. As the result of the drastic treatment to which they are subjected, many of the trees are killed after having been tapped a few times.

Another serious objection to the native procedure in many parts of West Africa is that the rubber collectors do not restrict their tapping operations to *Funtumia elastica*, but also include other trees, such as *Funtumia africana*, *Chlorophora excelsa*, *Conopharyngia crassa*, *Antiaris toxicaria*, and *Alstonia* sp., which yield a resinous latex. The latices of these trees are mixed with that of *Funtumia elastica* before coagulation, with the result that the rubber obtained contains a high percentage of resin and is consequently considerably depreciated in quality and value.

Native Methods of Preparing the Rubber.—The principal methods adopted by the natives for the production of Funtumia rubber are as follows:

(1) By allowing the latex to stand until spontaneous coagulation occurs; (2) by heating the latex; (3) by adding to the latex an infusion of *Bauhinia reticulata* leaves; and (4) by adding the juice of a Strophanthus vine (*Strophanthus Preussii*, Engl. and Pax), which is known as "Diecha" in the Gold Coast.

(1) *Spontaneous Coagulation.*—This plan is employed in the preparation of "lump" rubber, the form in which Funtumia rubber is chiefly prepared throughout West Africa. The native makes a shallow rectangular hole in the ground and lines it with clay in order to render it partially watertight. When the clay has dried, the

hole is filled with latex and covered with a piece of wood, or with plantain leaves, etc., in order to prevent dirt from falling in. The latex is then simply allowed to stand until coagulation has taken place and the mass of rubber produced has become sufficiently firm to be handled. The usual time required for this change to occur is about six weeks. The lump of rubber is then lifted from the hole and allowed to dry entire, sometimes being exposed to the sun for the purpose. As a rule no attempt is made by the natives to remove the excess of liquid from the rubber. The lumps thus prepared are afterwards stored in the roof of a native hut until they are sold to the traders.

The lumps of rubber vary considerably in size, those from the Gold Coast, for example, measuring from 4 to 10 in. in thickness. They consist of dark-coloured porous masses of rubber, which usually contain in their cavities a large quantity of the serum of the latex and frequently uncoagulated latex as well. Owing to the length of time occupied by the coagulation and to the moist condition in which the rubber is left, the proteins present in the latex undergo decomposition, with the result that the rubber develops a very offensive odour. On account of these defects the West African lump rubbers are of low quality and generally realise less than one-half the price of fine hard Para.

It is stated that at one time in the Gold Coast the lump rubber was cut into strips and the liquid pressed out, but that the practice was abandoned as the price obtained was not sufficient to compensate for the loss in weight and the labour involved.

(2) *Coagulation of the Latex by Heat.*—In applying this method the natives usually heat the latex in an iron or clay pot over a fire, stirring it with a stick until coagulation is complete. In Sierra Leone, where this method of preparation is common, the freshly coagulated rubber is either kneaded in the fingers to press out the liquid, or it is placed between banana leaves and stamped with the feet so as to form a flat cake. The rubber is then cut into thick strips, which are dried and wound into large balls known as "twists."

The drawback to this method of preparation as practised by the natives is that there is very considerable danger

of over-heating the rubber and rendering it sticky. Recently, however, improvements have been made in the process, which will be dealt with later in the section relating to plantation methods (see p. 174).

(3) *Coagulation of the Latex by means of an Infusion of Bauhinia reticulata Leaves.*—This method of coagulating Funtumia latex is employed by the natives in certain districts of West Africa. A hot infusion of the leaves is poured into a quantity of the undiluted latex and the mixture is stirred for a few minutes until coagulation occurs. The usual procedure has been described as follows:

About 1 lb. of the leaves is put into 3 gallons of water and boiled for 15 minutes; the infusion is then strained through calico and the hot liquid is added to about one gallon of latex, stirring well. Complete coagulation takes place quickly, usually within four or five minutes, and the rubber obtained may be pressed out into sheets or made into lumps or twists.

It is not always possible to employ this method of preparing Funtumia rubber, as *Bauhinia reticulata* does not invariably occur in the same localities as *Funtumia elastica.* The infusion of the leaves is acid and contains tannin, 8 per cent. of which was found in a sample of the dried leaves examined at the Imperial Institute. The tannin appears to be the active coagulating agent, and infusions of other astringent products, such as the pods of *Acacia arabica*, exert a similar action on the latex. It is of interest that an infusion of *Bauhinia reticulata* leaves is used by the natives of the French Sudan to coagulate the latex of *Landolphia Heudelotii.*

(4) *Coagulation of the Latex by means of the Juice of the "Diecha" Vine, Strophanthus Preussii.*—This method is used by the natives in some districts of the Gold Coast, and as it is very rapid and does not require the application of heat, it has recently been adopted to a considerable extent in that country. The young Diecha vines yield a milky latex when incisions are made in the bark, whilst the older vines give a clear yellowish fluid which is stated to be the most active as a coagulant. A small quantity of this liquid when added to Funtumia latex quickly causes coagulation in the cold on stirring, especially if the latex is a few days old. The resulting rubber may be made into sheets, lumps, or twists.

Cultivation of Funtumia elastica.—During recent years systematic attempts have been made by the Agricultural and Forest Departments in West Africa to encourage the planting of *Funtumia elastica* by the natives in order to replace the large numbers of the wild trees which have been destroyed by the drastic native methods of tapping, and in several countries considerable progress has already been made in this direction. In Southern Nigeria the Forest Department has established plantations of the trees for experimental purposes, and large numbers of communal plantations, many of which are now reaching the production stage, have been formed by the natives in the vicinity of their villages. Similar action has been taken in the Gold Coast, where the cultivation of Funtumia trees has also been undertaken by European companies. In the Cameroons and in the Belgian Congo, *Funtumia elastica* has also been extensively planted, and experiments on the cultivation of the tree are being conducted in Sierra Leone, Northern Nigeria, and Uganda.

The suitability of Funtumia trees for purposes of general cultivation cannot, however, be regarded as definitely established. It was thought at first that *Funtumia elastica*, being indigenous, would be the most satisfactory rubber tree for planting purposes in tropical Africa; but owing to the success which has attended the introduction and experimental cultivation of the Para tree in Africa, there is now a strong and growing opinion that the Para tree should be grown in preference wherever the climatic conditions are suitable. *Funtumia elastica* gives a very much smaller annual yield of rubber than the Para tree, it has a much thinner bark, and does not stand tapping so well. The results obtained in Southern Nigeria, the Gold Coast, and Uganda with the two species are greatly in favour of the Para tree, and indicate that in these countries very much better returns will be obtained by cultivating *Hevea brasiliensis* in suitable localities than by growing *Funtumia elastica*. In the Cameroons, too, the large plantations of *Funtumia elastica* which have been established by European companies are not being extended, but the Para tree is being planted instead. It is possible, however, that Funtumia trees may be more suitable than Para trees for cultivation by the natives, as they do not

require to be tapped continuously, but only once or twice a year, and there is the further advantage that they can be grown in situations which are too dry for Para trees.

The methods adopted for cultivating Funtumia trees and the improved methods of preparing the rubber which have been introduced are described in the following account:

Raising the Plants.—The plants are usually grown from seed, of which the trees produce large quantities. If carefully preserved, the seeds will retain their vitality for two or even three months, but it is desirable to sow them as soon as possible after collection. Well-drained seed-beds, consisting of a mixture of good soil and leaf mould, are prepared in a sheltered position, and the seeds are sown a few inches apart and lightly covered with fine soil. The beds are kept watered, and, if necessary, shaded from the sun. Germination usually takes place in from three to four weeks after sowing; and when the seedlings are about 4 in. high, they are transferred to nursery beds or are planted singly in baskets made of banana leaves or similar material. The young plants require to be regularly watered and provided with shade from the direct rays of the sun. When from six to nine months old they may be planted out, and it is desirable that this operation should be performed at the beginning of the rainy season, so that the plants are not exposed to drought after being placed in position. Holes are made in the usual way for the reception of the plants, 1 ft. square and 1 ft. deep if the soil is good, and 2 ft. square and 1½ ft. deep if poorer.

In Southern Nigeria the plan has been tried of transferring the seedlings direct to the plantation and erecting a shade over each until the young plants have become well established. This method has given very successful results and has been largely adopted in forming the native communal plantations of Funtumia trees.

Formation of Plantations.—Several methods of cultivating Funtumia trees have been tried. In some cases parallel lines have been cleared in the forest and the Funtumia trees planted at regular intervals in the clearings. This plan, however, is not satisfactory, owing to the fact that under these conditions the growth of the trees is very slow. Another method was to clear the

land, leaving the large forest trees standing in order to afford some shade for the young Funtumia plants. It has been found, however, that if this method is adopted, it is necessary to cut out the shade trees when the Funtumia trees are about two years old, as otherwise the growth of the latter is interfered with. The best results appear to be obtained by completely clearing the land so as to remove all shade, and then planting the Funtumia trees closely in coppice formation.

The trees were formerly planted rather widely, 15 by 15 ft. or 20 by 20 ft., but it was found that under such conditions the trees had a tendency to branch low down, and considerable pruning was required to obtain a stem suitable for tapping. Latterly this difficulty has been obviated by planting the trees very closely in order to encourage the development of a straight, erect stem, and then thinning out when they become too crowded. A commonly adopted distance for planting the trees is 6 by 6 ft. and they are gradually thinned to 12 by 12 ft. or 18 by 18 ft.

The plantation requires little attention during the early stages, beyond filling up any gaps which may occur and protecting the young plants from being overgrown by weeds. The thinning of the trees should be conducted during the third and fourth years, in order that the remaining trees may have a chance to increase in girth.

Diseases and Pests.—*Funtumia elastica* is not subject to any serious diseases or pests in West Africa. The young plants are sometimes attacked by the caterpillar of a moth (*Glyphodes ocellata*) which feeds on the leaves and may defoliate the trees. Two or three species of girdling beetle also do a certain amount of damage, the beetles themselves gnawing the bark of the young shoots whilst the larvae burrow in the wood. Two species of these beetles collected by Christy in the Cameroons were identified as *Chreostes coeca*, Cher., and *Monochamus ruspator*, Fab., whilst another species from Tarquah in the Gold Coast was *Acmocera conjux*, Thoms.

A fungoid root disease, similar to *Fomes semitostus*, has been found attacking Funtumia trees in the Gold Coast, and a "brown" root disease is also known.

None of these diseases or pests does much damage to the trees.

In Uganda a form of "canker," caused by a fungus which has been named *Nectria funtumiae*, Massee, develops on the stems of Funtumia trees and is very common in some districts. It begins as a black patch on the bark, and gradually spreads until it encircles the stem. The bark of the affected area becomes badly cracked, which seriously interferes with the tapping of the trees. This disease has not yet been noticed in West Africa.

Rate of Growth.—*Funtumia elastica*, if planted closely on good soil without shade, makes fairly quick growth, whereas if planted under shade it develops extremely slowly. In the following section particulars are given of the rate of growth of Funtumia trees in different countries:

Gold Coast.—Government plantations of Funtumia trees have been established in the Gold Coast at Aburi, Tarquah, and Coomassie.

The conditions of climate and soil at Aburi do not appear to be entirely suitable for the growth of *Funtumia elastica*, the rainfall being rather low. The trees, however, are healthy and show fairly satisfactory growth on the whole: where the soil is deep, they have made excellent growth, about equal to that of Para trees; but in places where the soil is shallow, they have done badly. The trees were planted 10 by 10 ft. apart in 1902–3, and the following table shows their average girth at different dates:

Date of planting.	Date of measurement.	Average girth at 3 ft. from ground.
		in.
1902–3	Jan. 1909	10·75
1902–3	,, 1910	13·00
1902–3	,, 1911	14·66
1902–3	,, 1912	15·91

At the end of 1909 there were 12,800 Funtumia trees in the Aburi plantation.

At Tarquah, where the rainfall is heavier than at Aburi, the cultivated Funtumia trees have made very good growth. Four-year-old trees planted 20 by 20 ft. had an average girth of 14½ in. at 3 ft. from the ground, whilst trees of similar age planted 15 by 15 ft. had an average girth of 13 in. According to measurements

From the Collections of the Imperial Institute

FUNTUMIA TREES AT TARQUAH, GOLD COAST

Trees six years old

made by Christy,* a block of 3½-year-old Funtumia trees at Tarquah, planted 10 by 10 ft., had an average girth of 9¼ in., and a block of 5½-year-old trees, planted 20 by 20 ft., averaged 15¼ in. in girth.

SOUTHERN NIGERIA.—Christy has published the following details regarding the size of cultivated Funtumia trees growing in the Mamu Forest Reserve and in a native communal plantation near Benin City:

District.	Age of trees.	No. measured.	Planting distance.	Girth. Average	Girth. Maximum.	Average height.	Height of tappable stems.
	Years.		ft.	in.	in.	ft.	ft.
Mamu Reserve .	10	50	6 × 12	21¾	28	45	15–18
,, ,,	10	51	30 × 50	21¼	30¾	40	6–8
Benin City .	7	200	5 × 5	14	20¼	32–35	20

UGANDA.—The following measurements of *Funtumia elastica* trees growing in the Botanic Gardens at Entebbe have been published:

Date of planting.	Date of measurement.	Height. ft.	Height. in.	Girth at 3 ft. from ground. ft.	Girth at 3 ft. from ground. in.
September, 1903 . .	March 31, 1907	12	1	0	9¾
,, ,, . .	,, 1908	15	8½	1	2¼
,, ,, . .	,, 1909	24	2	1	4¼

CAMEROONS.—The following measurements taken by Christy at the Victoria Botanic Gardens in the Cameroons are regarded by him as representative of the growth of *Funtumia elastica* trees in that country:

Age of trees.	Number of trees measured.	Planting distance.	Girth. Average	Girth. Maximum.	Average. height.	Height of tappable stems.
Years.		ft.	in.	in.	ft.	ft.
9½	44	12 × 30	23½	28¾	30–35	10–12
9½	23	18 × 15	25¼	32¾	25	8
7½	223	9 × 9	21	29	25–30	15–18

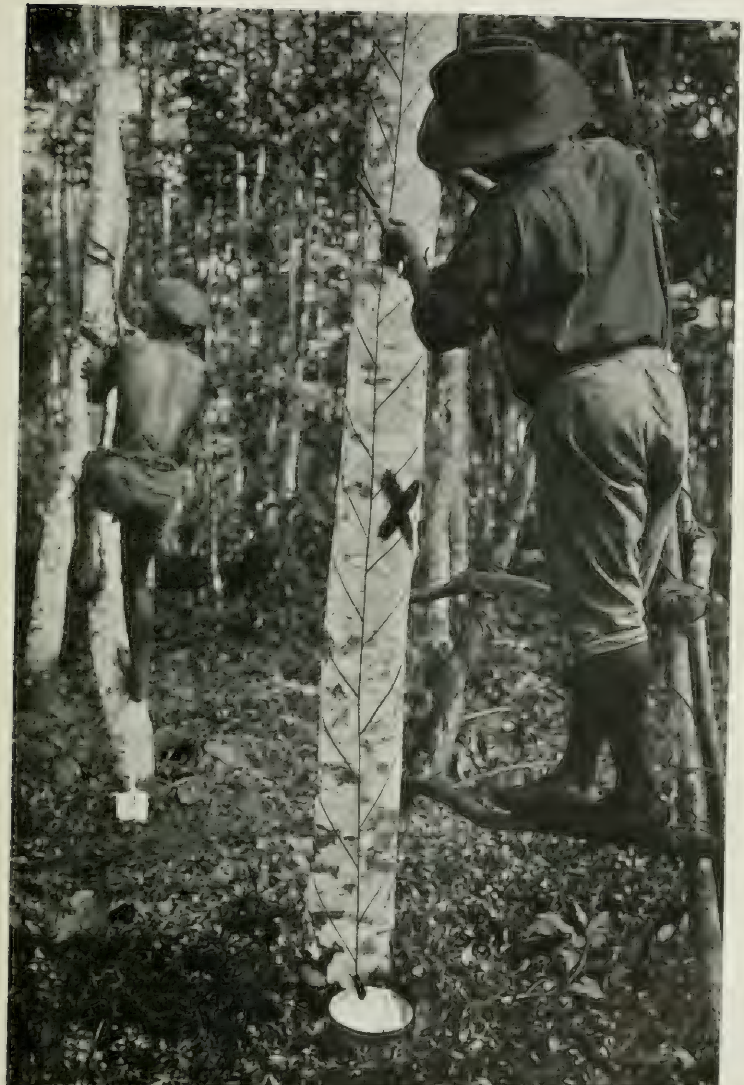
Plantation Tapping Methods.—*Funtumia elastica* differs fundamentally from *Hevea brasiliensis*, the Para tree,

* See *The African Rubber Industry and Funtumia elastica*, by Cuthbert Christy (London: John Bale, Sons & Danielsson, Great Titchfield Street, W.).

in its behaviour on tapping. It has been pointed out already that the latter tree can be repeatedly tapped for long periods, whereas Funtumia trees yield practically all their available latex at a single tapping and can only be tapped once or twice a year. The methods employed for Para trees cannot, therefore, be used for tapping *Funtumia elastica*. The bark of the Funtumia tree is also much thinner than that of the Para tree and is consequently not so suitable for tapping purposes.

Cultivated Funtumia trees are not usually tapped until they have attained a girth of at least 18 in. at 3 ft. from the ground, and the method of tapping most commonly adopted is the double-herringbone system (see p. 66). The incisions are generally restricted to one-half of the tree, and the two halves are tapped alternately. In some cases, however, each set of incisions is restricted to one-third of the circumference of the stem, and two vertical columns of untapped bark are left between them at opposite sides of the trunk in order to ensure that the vital functions of the plant are not interrupted. The incisions are frequently carried to the top of the stem; but in Southern Nigeria regulations were introduced in 1910 whereby cultivated Funtumia trees are not to be tapped to a greater height than 10 ft. from the ground. The lateral cuts are made from 8 to 12 in. apart, and, according to Christy, incisions every 8 in. will furnish the whole of the available latex, no further flow being obtained if additional incisions are subsequently made between the previous series. The trees are usually tapped only once, or at most twice, in the year on alternate sides.

A V knife or a gouge is generally used for making the incisions, portions of the bark being excised. Christy, however, has suggested an incision method in which shallow grooves, not reaching to the laticiferous tissue, are cut in the bark by means of a V knife with rounded apex, and the latex is then liberated by a rowel pricker with a thin sharp blade. This method has been very favourably received both in West Africa and in Uganda, as it gives a good yield of latex and the cuts heal rapidly. Experiments conducted on Funtumia trees at the Mamu Forest Reserve in Southern Nigeria showed that incisions made by Christy's method healed almost completely within a month or so, and it was considered



From the Collections of the Imperial Institute

FUNTUMIA TREES IN SOUTHERN NIGERIA, SHOWING METHODS OF TAPPING

that by using this system it may be possible to tap the trees two or three times a year without diminishing the yield. Similar trials made on trees growing in the native communal plantations in the Benin City district of Southern Nigeria did not give such satisfactory results, however, so far as the healing of the incisions was concerned, and it is evident that further observations on the point are necessary. The possible effect of the pricker in producing excrescences of the wood, as in the case of Para trees, will also have to be borne in mind, as it may not become apparent for some time.

Christy has recommended a method of tapping Funtumia trees which he describes as the double half-spiral system. It is a double-herringbone system over the whole stem, the lateral cuts being made 8 in. apart and extending round half the circumference. In retapping, fresh lateral incisions are made from 1½ to 2 in. above the old cuts and a new vertical channel is also cut at the side of the first. He states that incisions made with the groover and pricker heal rapidly, and that if the trees are tapped two or three times a year by the above method, the renewed bark will be ready for retapping by the time the bark between the first lateral cuts has been used up. This method is said to give fair yields of latex regularly year by year with the least possible injury to the tree.

A system of vertical incisions has also been tried in the Cameroons for tapping *Funtumia elastica*. In this method two or more parallel vertical cuts are made in the bark, extending from the foot of the tree to various heights, and the latex is collected at the base. Sometimes shallow grooves are first cut in the bark, and the latex is then liberated with the point of a pruning-knife. Subsequent incisions are made at the side of the previous cuts. This method gives a very fair yield of latex, and the results of experiments made with it in the Gold Coast and Southern Nigeria will be found on pp. 178 and 180.

A number of well-known tapping tools, designed specially for the Para tree, have been tried in Southern Nigeria for *Funtumia elastica*, but it is stated that besides Christy's knife and pricker, only the "Para," the "Secure," the "Sculfer," and Messrs. Walker and Sons' knives were at all suitable for the purpose.

Coagulation of Funtumia Latex.—The coagulation of the latex of *Funtumia elastica* presents a number of interesting features, the most important of which is that it is much more difficult to induce complete coagulation in fresh latex than in that which has been kept for one or more days. In consequence of this fact processes of coagulation which answer well for old latex are sometimes ineffective or only partially successful when applied to latex which has just been collected from the trees.

The methods of coagulation which have been proposed for use on plantations may be grouped under the following heads: (1) by allowing the latex to stand until coagulation occurs; (2) by creaming; (3) by boiling; and (4) by the addition of coagulants.

Spontaneous Coagulation.—Attempts have been made to prepare Funtumia rubber in biscuits by allowing the latex to stand in shallow vessels until coagulation has taken place. If glazed vessels are used, however, the process is too slow to be of practical value, as complete coagulation may take as long as three weeks.

A modification of this method, in which the latex is allowed to stand in shallow trays of soft wood, has been successfully employed in the Cameroons. The wood absorbs the aqueous portion of the latex, and in two or three days a sheet of rubber is left in the tray.

Creaming.—If Funtumia latex be diluted with five to ten times its volume of water, it "creams" on standing, and a coherent cake of rubber is finally obtained. This method is, however, slow, like that of the spontaneous coagulation of the undiluted latex, and the formation of the cake of rubber may take a week.

Boiling the Latex.—This method has been adopted in Southern Nigeria for the preparation of rubber from the communal plantations of Funtumia trees, as it is the most suitable for native use. It has been found that the latex does not coagulate quickly unless actually boiled, so that the use of a double pan has been abandoned and the diluted latex is heated directly in the following manner:

One and a half pints of water are placed in a 3-pint saucepan and raised to the boiling point, when ½ pint of latex is added. The rubber which separates is kept off the sides of the vessel by stirring with a stick, and the

heating is continued until the solution is left clear. The rubber thus obtained is at once rolled out into a sheet by means of a wooden roller, and is subsequently well washed and dried.

Fresh latex, it may be observed, is very difficult to coagulate completely by boiling; but if the latex is allowed to stand for twelve hours before being treated, the process is quite easy and effective.

It is stated that the latex may also be conveniently coagulated by passing steam into it.

Addition of Coagulants.—The principal coagulants which have been proposed for preparing Funtumia rubber are tannic acid, mercuric chloride (corrosive sublimate), and formalin.

If Funtumia latex which has been kept for a few days be diluted with hot water and a solution of tannic acid or mercuric chloride added, complete coagulation is immediately induced; but if fresh latex be used, only slow creaming takes place. Christy states, however, that if a little acetic acid be added to the fresh latex diluted with hot water, the addition of tannic acid or mercuric chloride then produces immediate and complete coagulation, although the acetic acid has no coagulating action by itself. Hot water is essential for the success of this method, as if cold water be used only slow creaming takes place with both fresh and old latex.

The process recommended by Christy for the coagulation of fresh Funtumia latex by means of tannic acid is as follows:

A stock solution of tannic acid is made by dissolving 1 lb. of tannic acid in 16 oz. of water and adding 5 oz. of acetic acid. 1 oz. of this solution is poured into 20 pints of hot water at 80° F., and 5 pints of fresh latex are then added and well mixed with the acid solution. Coagulation quickly occurs and may be facilitated by gentle agitation of the vessel.

Mercuric chloride may be employed in the same way, but on account of its very poisonous properties it is not so suitable as tannic acid for general use.

Funtumia latex can also be coagulated by the addition of formalin (formaldehyde), which is frequently added to other latices to retard their coagulation. According to Christy, the addition of 15 cc. of commercial formalin

(containing 40 per cent. formaldehyde) to 1 pint of freshly collected latex will induce coagulation in from 15 to 40 hours, depending on the dilution of the latex. This process is reported to give rubber of good quality and possesses the advantage that it can be used for fresh latex.

In Uganda, and also in West Africa, Funtumia rubber is now being prepared by machinery in the form of crêpe or sheet.

Yield of Rubber from Funtumia elastica.—With reference to the yield of rubber furnished by wild Funtumia trees in West Africa, Chevalier has recorded that in the Ivory Coast, full-grown trees, probably 100 years old with trunks 60 ft. high and 24 in. in diameter, have given as much as 8 to 10 quarts of latex, representing 4½ to 6½ lb. of rubber, when cut down by the natives at the beginning of the rainy season. If the trees are tapped, he considers that 1 lb. of rubber is the maximum yield from the first tapping of a full-grown tree, whilst ten- to twelve-year-old trees will only give 3½ to 5½ oz. The subsequent tappings will give smaller amounts.

In the Cameroons, Schlechter obtained 3 quarts of latex, giving 3½ lb. of dry rubber, from a tree said to be seven years old and never previously tapped, but this appears to be an unusually high yield. According to Dudgeon, 2 quarts of latex (corresponding to about 2 lb. of rubber) is an exceptional yield from a large tree in British West Africa.

Other recorded yields of rubber from wild Funtumia trees vary from 4 oz. to 1 lb. or more, depending on the size of the tree, its condition, and the period which has elapsed since the previous tapping.

The yields so far obtained from cultivated trees have usually been much smaller than from the wild trees.

The following account gives the results of tapping experiments on Funtumia trees in different countries:

Gold Coast.—I. Some preliminary tapping experiments were conducted during the latter part of 1909 on five groups of *Funtumia elastica* trees growing at the Aburi plantation, and the results obtained are summarised in the following table:

Group.	No. of trees.	Average girth.	Method of tapping.	No. of tappings.	Total yield of rubber.	Average total yield per tree.
		in.			oz.	oz.
I.	15	18½	Full herringbone to a height of 6 ft.; first lateral incisions 12 in. apart and subsequent tappings 1½ in. below previous cut.	7 at intervals of 10 days.	12·1	0·807
II.	15	19	Vertical parallel cuts, 1½ in. apart to height of 6 ft.	Do.	14·34	0·956
III.	15	18¾	Half herringbone on half of tree to height of 6 ft.; first lateral incisions 9 in. apart and subsequent tappings 1 in. below previous cut.	Do.	9·17	0·611
IV.	15	—	Full herringbone on whole of tree to height of 6 ft.; first lateral incisions 9 in. apart and subsequent tappings 1 in. below previous cut.	Do.	20·45	1·36
V.	15	18½	Native method, viz. full herringbone to height of 15 ft.	1	20·1	1·34

It is interesting to note that in these trials the native system of tapping gave the best results. The yield of rubber per tree obtained by this method was only slightly below the highest yield furnished by the other systems employed, and the cost of collection was considerably less. All the yields were, however, very small.

II. During 1910–11 an experiment on a larger scale was made at Aburi, in order to determine (1) the best time to tap Funtumia trees; (2) the comparative yield from trees of different girth; and (3) the average yield per tree at the first and subsequent tappings. 425 trees, which were just over ten years old at the beginning of the experiment, were divided, according to girth, into five groups as follows:

Group.	No. of trees.	Range of girth.	Average girth. Before experiments.	Average girth. After experiments.
		in.	in.	in.
A . .	78	10–12	11·18	11·53
B . .	100	12–14	13·25	13·81
C . .	104	14–16	15·01	15·56
D . .	80	16–18	16·88	17·45
E . .	63	over 18	19·12	19·56

The trees of Group A were used for check experiments, and the trees of the other groups were subdivided into three lots, which were tapped at intervals of two, four, and six months respectively. The vertical system of tapping was adopted as most suitable for the experiments, the Christy knife and pricker being employed. At each tapping three vertical cuts were made at equal distances apart to a height of 100 inches from the base of the tree, and the subsequent incisions were placed 1½ to 2 in. at the side of the previous cuts.

The following table shows the results obtained:

AVERAGE YIELD (IN GRAMS) OF DRY RUBBER PER TREE

I. Two-month intervals

Group.	No. of trees.	Oct.	Dec.	Feb.	April.
B 1 .	32	16·4	7·7	5·4	—
C 1 .	33	16·3	11·2	12·0	—
D 1 .	26	12·6	12·4	8·0	3·8
E 1 .	21	20·3	18·0	9·0	7·5

II. Four-month Intervals

Group.	No. of trees.	Oct.	Feb.	June.	Oct.
B 2 .	33	14·7	9·1	8·7	—
C 2 .	35	18·1	12·6	8·3	—
D 2 .	27	15·9	10·8	8·6	3·5
E 2 .	21	22·0	12·5	13·2	8·3

III. Six-month Intervals

Group.	No. of trees.	Oct.	April.	Oct.
B 3	35	13·8	6·8	4·8
C 3 . . .	36	18·0	8·5	7·8
D 3 . . .	27	23·3	10·8	7·5
E 3	21	26·6	22·2	8·4

It will be seen from these results that the largest trees gave the most rubber and that the yield was diminished very considerably by repeated tappings. It is interesting, however, that the yield after a two months' interval was practically as good as that after four or six months. With reference to the best time for tapping, it was found that

the yield was much better in October to December than in February to April, whilst tappings in June also gave good results. It is concluded that in the Gold Coast the best time for tapping Funtumia trees is from June to December or January, which includes the period from about the middle of the rainy season to the commencement of the harmattan.

The total yield of rubber obtained in these experiments extending over thirteen months was 31 lb. 15 oz., equal to an average yield of only 1·31 oz. per tree, which is a very small return.

III. In another experiment in the Gold Coast, twenty-five trees, 15½ in. in average girth, were tapped six times during eleven days by a herringbone system in March 1911, and gave the following results:

	20th.	24th.	25th.	28th.	29th.	30th.
Dry rubber in grams .	317	418	202	186	224	120

The total yield was 1,467 grams (51½ oz.), equal to 2·06 oz. per tree.

Southern Nigeria.—I. A series of tapping experiments on Funtumia trees growing in the Mamu Reserve was carried out by the Forest Department in December 1909. The half-herringbone, full-herringbone, and spiral methods were tried, and also the system of making a number of straight vertical cuts down the stem. The results obtained are summarised in the following account:

(*a*) Ten eight-year-old trees, 22·6 in. in average girth, which had not been tapped previously, were treated by the half-herringbone system, the vertical channel being 10 ft. long and the lateral incisions 6 in. apart. After the first tapping the trees were allowed to rest for a few days and were then tapped four times on alternate days by making fresh lateral cuts below the previous incisions. The yields of fresh biscuit rubber were as follows:

	oz. per tree.
1st tapping	1·9
2nd ,, ...	0·375
3rd ,, ...	0·325
4th ,, ...	0·075
5th ,, ...	nil
Total . . .	2·675

(*b*) A tree tapped in 1908 by the half-herringbone system was tapped again on another side :

	oz.
Yield of fresh rubber in 1908	2
,, ,, ,, 1909	$1\frac{1}{2}$

(*c*) Two trees tapped in 1908 by the half-herringbone system were tapped again by making new lateral cuts below the previous incisions :

	oz.
Yield of fresh rubber per tree in 1908 . .	2
,, ,, ,, ,, 1909 . .	$\frac{1}{4}$

(*d*) Two trees were tapped by the half-herringbone system, the lateral incisions being 12 in. apart in one case and 6 in. in the other.

Yield of rubber from tree 24 in. in girth with lateral incisions 12 in. apart was $1\frac{3}{4}$ oz.

Yield of rubber from tree 22 in. in girth with lateral incisions 6 in. apart was $1\frac{1}{2}$ oz.

(*e*) A tree, 24 in. in girth, was tapped by the spiral system, the spirals being 1 ft. apart. After two days a new spiral cut was made between the first incisions :

	oz.
Rubber from 1st tapping	$4\frac{1}{2}$
,, ,, 2nd ,, ...	$\frac{3}{4}$

A tree 12 in. in girth tapped by the spiral system gave $\frac{3}{4}$ oz. of rubber.

(*f*) A tree, 24 in. in girth, was tapped by making four vertical parallel cuts 16 ft. high ; after two days four other cuts were made between the first incisions.

	oz.
Rubber from 1st tapping	$2\frac{1}{2}$
,, ,, 2nd ,, ...	$1\frac{1}{2}$

(*g*) A tree, 20 in. in girth, was tapped by making four vertical parallel cuts to a height of 8 ft. ; when the flow of latex ceased the cuts were continued to a height of 16 ft.

	oz.
Rubber from 1st tapping . .	1
,, ,, 2nd ,, . . .	$\frac{1}{2}$

(*h*) A tree was tapped by the full-herringbone system, the vertical channel being 8 ft. long and the lateral incisions 1 ft. apart. The lateral cuts were reopened on alternate days by paring the lower surface in the manner adopted for Para trees :

	oz.
Rubber from 1st tapping . .	1·5
,, ,, 2nd ,, . .	0·5
,, ,, 3rd ,, . .	0·25
,, ,, 4th ,, . .	0·2
,, ,, 5th ,, . .	
Total	2·45

No definite conclusions as to the best method of tapping can be drawn from these experiments, but the results may be summarised as follows :

(1) The spiral system gave the best yield of rubber and then the method of long, vertical cuts.

(2) There appeared to be no wound response, as the yield of rubber steadily diminishes with successive tappings.

(3) The yield of rubber obtained from a tree after a year's interval was less than the original yield, no matter whether the new tapping was made on the same side of the tree or on the opposite side.

II. The trees which were tapped in 1909 for the first time were retapped on the same area in 1910, but the results were very poor, the amount of latex obtained being only one-tenth of that yielded in 1909.

III. During 1911 tapping experiments on the Funtumia trees in the Mamu Reserve were undertaken on a larger scale: 5,456 trees were tapped, of which 2,039 were wild trees and the remainder cultivated trees. The full-herringbone system was employed, the cultivated trees being tapped by means of the Christy knife to a height of 12 ft. and the wild trees by the native knife

to the first branch. The total yield of dry rubber from the 5,456 trees was 702 lb., or approximately 2·06 oz. per tree.

The experiments were continued during 1912, tapping being commenced on both wild and planted trees on May 1. Up to the end of June the results obtained were as follows :

	Number of trees tapped.	Weight of dry biscuit rubber.	Average yield of dry biscuit rubber per tree.
		lb.	oz.
Plantation trees . .	1,954	114·6	0·93
Wild trees . . .	354	40·5	1·8

It was stated that the wild trees gave a poor yield of rubber for their size, owing to the drastic treatment they received years ago; but notwithstanding this, they furnished twice as much rubber as planted trees 18 in. or more in girth.

In these experiments the rubber was prepared by boiling the diluted latex and was subsequently smoked. The cost of tapping and preparation was approximately 1*s.* 8*d.* per lb.; but it is stated that this figure will be reduced as the tappers become more expert.

IV. In 1910 eighty-four of the native communal plantations of Funtumia trees, which have been established in Southern Nigeria, were tapped for the first time under the direction of the Forest Department. The plantations were also thinned at the same time, the trees to be removed being marked by a Forestry officer and then tapped to exhaustion before being cut down. 4,706 of the permanent trees, 18 in. and over in girth, were tapped once by the full-herringbone system to a height of 10 ft., the cuts extending half-way round the stem. The total yield of dry rubber was 413 lb. 12 oz., equivalent to a yield of 1·406 oz. of dry rubber per tree. In addition, 28,815 trees were tapped to exhaustion and cut out, the majority of these being, however, very small and scarcely worth tapping: they furnished 608 lb. 4 oz. of dry rubber, or an average yield of 0·337 oz. per tree.

Three hundred of the native communal plantations in the Central Province of Southern Nigeria were tapped during 1911. A yield of 1,885 lb. 11 oz. of dry rubber was obtained from 20,210 permanent trees, equal to a yield of 1·49 oz. per tree. 52,166 trees were also tapped to exhaustion and cut out, yielding 1,064 lb. 12 oz. of dry rubber, or an average of 0·326 oz. per tree. These yields agree closely with those obtained the previous year.

Uganda.—The average yield of dry rubber from mature Funtumia trees in the Uganda forests, when tapped to a height of 30 ft., is placed by Fyffe at 5 or 6 oz. per annum.

In an experiment conducted by Dawe in the Bugoma forest, fifty Funtumia trees were taken haphazard in different parts of the forest. They had an average girth of 27½ in. and were tapped to a height of 22 ft. The average yield of dry rubber per tree from the single tapping was 3½ oz. The quantity of latex furnished by the different trees ranged from 2¼ to 20 fluid oz., thus showing a very considerable variation in the yield from different trees.

Christy has published the results of a number of tapping experiments on wild Funtumia trees in Uganda by the pricker method. Twenty-eight trees varying in girth from 19¾ to 46½ in. were tapped, mostly to a height of 30 ft. The yield of latex ranged from 3·13 to 20 fluid oz. per tree, and the amount of dry rubber from 0·36 to 5·14 oz. per tree from the single tapping.

In the Mabira forest of Uganda over 400,000 wild Funtumia trees, 18 in. or more in girth, have been tapped during a single year, and the average yield of dry rubber per tree amounted to 3 oz.

Cameroons.—Large numbers of Funtumia trees have been planted in the Cameroons, and, according to Preuss, the average yield of rubber obtained by tapping several hectares of eight- to nine-year-old trees was not more than 40 grams (1·4 oz.) per tree. More recently the yield has been increased to 60 to 70 grams (2·1 to 2·4 oz.) per tree.

Individual trees may give much larger yields, but the above figures are valuable as representing the results of tapping cultivated Funtumia trees on a fairly large scale.

Belgian Congo.—The following results of tapping

experiments made with *Funtumia elastica* trees growing in the Belgian Congo have been recorded:

District.	No. of trees tapped.	Age.	Tapping method.	Yield of dry rubber per tree.
		Years.		oz.
Bokala (Middle Congo) .	10	9	Tapped during 10 days	2¼
Coquilhatville (Equateur)	62	8	Single tapping	2½
Eala (Equateur) . .	2	8	Three tappings at intervals of one month	2¾
Do. . .	6	8	Do.	3
Libenge (Ubangi) . .	241	8	Single tapping	2
Do. . .	127	—	Do.	2
Do. . .	99	—	Do.	1¾
Do. . .	114	—	Do.	2
Do. . .	96	—	Do.	1½
Bangala . . .	1	6–7	Tapped during 2 days	6½
Do. . . .	1	8	Do.	3¼
Do. . . .	1	8	Do.	6¼

Composition of Funtumia Rubber.—The following analyses, made at the Imperial Institute, illustrate the composition of a number of specimens of Funtumia rubber obtained from different countries and prepared by different methods. Samples of the rubber in the form of biscuits, sheet, and crêpe are included, as well as specimens of native "lump."

It will be seen that some of the specimens of lump rubber are exceedingly resinous, indicating that the latex of *Funtumia elastica* was adulterated with other inferior latices in their preparation. The rubber in the form of biscuits, sheet, and crêpe is usually of very good quality, although the percentages of resin and protein are frequently fairly high.

Country.	Description of rubber.	Composition of dry washed rubber.			
		Caoutchouc.	Resin.	Protein.	Ash.
		Per cent.	Per cent.	Per cent.	Per cent.
Sierra Leone .	Sheet rubber, latex boiled without addition of water . .	86·9	5·9	6·0	1·2
Do. .	Sheet rubber, latex diluted with equal quantity of water and boiled . . .	91·3	5·7	2·6	0·4
Do. .	Sheet rubber, latex diluted with ten times its volume of water and boiled . .	91·4	6·4	1·9	0·3
Gold Coast .	Biscuit rubber, latex allowed to coagulate spontaneously .	84·6	5·8	8·3	1·3
Do. .	Do. Do.	82·6	6·9	8·9	1·6
Do. .	Biscuit rubber, latex coagulated by addition of formalin . .	79·5	10·5	9·3	0·7
Do. .	Biscuit rubber prepared by natives .	87·6	9·9	2·2	0·3
Do. .	Sheet rubber, latex coagulated with infusion of *Bauhinia reticulata* leaves .	88·5	8·7	2·3	0·5
Do. .	Do. Do.	89·6	8·1	1·9	0·4
Do. .	Do. Do.	88·6	8·9	2·1	0·4
Do. . .	Crêpe rubber, latex coagulated by juice of Diecha vine . .	85·4	10·5	3·5	0·6
Do. .	Lump rubber, latex coagulated by juice of Diecha vine . .	81·1	10·7	7·2	1·0
Southern Nigeria	Sheet rubber, latex coagulated by boiling after dilution with water . . .	89·4	8·6	1·6	0·4
Do.	Do. Do.	88·3	8·9	2·4	0·4
Do.	Do. Do.	87·0	9·2	3·1	0·7
Do.	Benin Lump . .	83·6	8·9	6·7	0·8
Do.	Do. . .	67·5	22·6	8·2	1·7
Northern Nigeria	Lump rubber . .	50·1	39·1	5·1	5·7
Liberia . .	Do. . . .	89·2	7·2	2·2	1·4
Do.	Do. . . .	78·1	12·9	8·1	0·9
Do.	Do. . .	85·5	6·9	6·5	1·1
Uganda . .	Biscuit rubber . .	86·1	6·5	6·6	0·8
Do. .	Sheet rubber .	90·3	7·7	1·7	0·3

CHAPTER XII

THE AFRICAN RUBBER VINES

African Rubber Vines.—The rubber vines belong to the two natural orders Apocynaceae and Asclepiadaceae, those of the former order being much the more important. They occur especially in tropical Africa, where they are very widely distributed, and are also found in Asia and America. Lists of the principal rubber vines, with their geographical distributions, have been given previously (see pp. 40–1), and in the following account it is proposed to deal in detail with the African vines.

The principal rubber-yielding vines occurring in Central Africa belong to the three genera Landolphia, Clitandra, and Carpodinus of the natural order Apocynaceae, whilst species of Cryptostegia belonging to the order Asclepiadaceae are found in Madagascar. A number of other genera of the Asclepiadaceae, *e.g.* Periploca, Dregea, and Asclepias, are represented by rubber-yielding species, but these plants are of little value as commercial sources of rubber. The most important African vines are *Landolphia Heudelotii*, A.DC. ; *Landolphia owariensis*, Beauv. ; *Landolphia Klainei*, Pierre ; *Landolphia Kirkii*, Dyer ; *Landolphia Dawei*, Stapf ; and *Clitandra orientalis*, K. Schum., with the closely related, if not identical, forms *Clitandra elastica*, Chev., and *Clitandra Arnoldiana*, De Wild. The vines of lesser importance are included in the previous list already referred to.

In addition to the vines there are a number of bushy plants belonging to the genera Landolphia, Clitandra, and Carpodinus which furnish " root rubber " from their underground stems (rhizomes). The chief of these are *Landolphia Thollonii*, Dewèvre ; *Landolphia parvifolia*, K. Schum. ;

Landolphia chylorrhiza, Stapf; *Clitandra henriquesiana*, K. Schum.; and *Carpodinus gracilis*, Stapf.

Attention may again be drawn to the fact that a considerable number of Apocynaceous vines contain latex which does not yield rubber, but only a resinous product, so that it is necessary to discriminate between the useful and the worthless species. Some of the vines which do not furnish rubber, *e.g.* *Landolphia florida*, Benth., are very widely distributed throughout tropical Africa.

The rubber plants belonging to this group occur over practically the whole of Central Africa and in Madagascar, their limit in the north extending from Senegambia to Abyssinia, and in the south from Portuguese West Africa to Zululand. In many districts within this area rubber vines were formerly extremely abundant, and the greater part of the wild rubber produced in Africa is still derived from them.

Botanical Characters.—The three genera Landolphia, Clitandra, and Carpodinus belong to the same tribe of the natural order Apocynaceae and are very closely related. The majority of the species are woody climbers, many of which attain a very large size. The climbing is effected by means of strong hook-branched tendrils which may be either terminal or axillary. In some cases, however, the plants are dwarf shrubs or undershrubs which have partly herbaceous branches or throw up fresh shoots annually, and certain species which occur normally as vines in the forests develop a bushy habit when growing upon open ground where there are no trees to serve as supports.

The leaves are simple, opposite, and vary considerably in size in the different species. The flowers are salver-shaped, resembling jasmine, and are usually sweet scented; they are arranged in terminal or axillary cymes which may be few- or many-flowered. In some cases the flowers are of considerable size and are produced very profusely in large, compact clusters. The fruit is a rounded or pear-shaped berry, varying from less than 1 in. to 10 in. in diameter, and is often brightly coloured; the fruits are frequently eaten by the natives. The seeds are either few or many, and are embedded in the juicy pulp of the fruit.

The characters of the principal African rubber vines are briefly given in the following descriptions. For fuller particulars reference should be made to the section on the Apocynaceae by Dr. Otto Stapf in the *Flora of Tropical Africa.**

Landolphia Heudelotii, A.DC.—This plant occurs both as a shrub and as a climber with branched tendrils (modified inflorescences). The leaves are oblong to elliptic or sublanceolate, with obtusely subacuminate or obtuse or subacute apex, and are obtuse or subacute at the base; 1 to 3 in. long and ¾ to 1¼ in. broad. The flowers are strongly scented and are arranged in shortly peduncled or sessile many-flowered corymbs or in elongated panicles; the corolla tube is whitish, slightly tinged with yellow, and the lobes pure white. The fruit is pear-shaped or globose, from 1 to 3 in. in diameter, yellow, and has a coriaceous rind.

Landolphia Heudelotii has not such a wide distribution as some of the other species, being restricted to the extreme western portion of tropical Africa. It is found in the coastal regions of this area from Senegal to Sierra Leone, and also occurs in the southern districts of the French Sudan as far east as Bobo-Dioulasso, and in the northern portion of the Ivory Coast. In the French Sudan it occurs commonly as a bush on the dry lateritic plains where there is no rainfall for about six months of the year, and appears to thrive under such conditions; in the forests of the coastal regions it develops as a vine. The rubber which it furnishes is of very good quality. According to Chevalier, 2,000 tons of rubber have been obtained annually since 1895 from *L. Heudelotii* in French West Africa.

Landolphia owariensis, Beauv.—A climbing shrub, frequently attaining a large size, with long hook-branched tendrils (usually more or less modified inflorescences). The leaves are oblong with acuminate or almost obtuse apex, and are subobtuse or subacute at the base; 3 to 6 in. long and 1 to 3 in. broad. The flowers, which occur in shortly peduncled, many-flowered panicles, are small and white, but soon turn brown. The fruit is spherical, 1 to 2½ in. in diameter, yellow mottled with red, and the woody rind is wrinkled or irregularly grooved. (See Plate X.)

* London: Lovell Reeve & Co., Ld., Henrietta Street, Covent Garden.

Landolphia owariensis, Beauv.

Landolphia Kirkii, Dyer
Landolphia Rubber Vines

This vine is very widely distributed over a large portion of tropical Africa. Its western limit is French Guinea, whence it extends eastwards, through Sierra Leone, the Gold Coast, and Nigeria, across the continent into the Bahr-el-Ghazal Province of the Anglo-Egyptian Sudan; south of this line it occurs throughout the Cameroons, the French and Belgian Congo, and also in Angola. Normally the plant is found as a vine, but it also occurs as a bush in open country. Chevalier considers that the species *L. humilis*, K. Schum., from the Congo is really the bushy form of *L. owariensis*.

The rubber furnished by *L. owariensis* is of excellent quality, and the vine is one of the principal sources of African rubber.

Landolphia Klainei, Pierre.—A climbing shrub, usually attaining a very large size, with long branched tendrils (modified inflorescences). The leaves are oblong, gradually tapering to an obtuse or subacute acumen, and rounded or shortly subacute at the base; 5 to 10 in. long and 1½ to 3 in. broad. The flowers occur in dense, subsessile, many-flowered corymbs or in elongated panicles. The fruit is globose and very large, from 6 to 10 in. in diameter, yellow when mature, with hard rind.

L. Klainei is one of the most vigorous of the African rubber vines and is noteworthy in having such very large fruits. It is an important source of rubber in the Belgian Congo, and also occurs in the French Congo, the Cameroons, and the Gaboon. This vine has been recorded from the Gold Coast, but does not appear to be abundant in that country.

Landolphia Kirkii, Dyer.—A climbing shrub with long branched tendrils (modified inflorescences). The leaves are very variable in size on the same branch, lanceolate to oblong, rarely more or less ovate or elliptic, usually gradually tapering into a short obtuse acumen, and shortly acute or obtuse at the base; 1 to 4 in. long and from 1 to 1¼ in. broad. The flowers are whitish and are arranged in dense, subsessile, many-flowered corymbs or in somewhat loose panicles. The fruit is obovoid-globose, and from 1¼ to 3 in. in diameter. (See Plate X.)

L. Kirkii is the most important rubber vine in East Africa, where it is very widely distributed. It occurs in Abyssinia, the East Africa Protectorate (but not in

Uganda), German and Portuguese East Africa, Nyasaland, Rhodesia, the eastern portion of the Transvaal, and Zululand. The wild rubber collected in the above area is principally derived from this vine. The product is of very good quality.

Landolphia Dawei, Stapf.—A scandent shrub which has not been observed to have tendrils. The leaves are oblong, shortly acuminate, and subacute or obtuse at the base, 4 to 8 in. long and 1¾ to 2¼ in. broad. The flowers are grouped in dense subsessile corymbs which occur at the end of the branches or arise from the axils of the uppermost leaf pairs. The plant is closely allied to *L. owariensis* and *L. Klainei*, but is easily distinguished from these species by its much larger flowers.

This vine occurs in Uganda and probably in the Belgian Congo. It gives a large yield of rubber, which is of very good quality.

Landolphia Thollonii, Dewèvre.—A dwarf shrub from 6 to 12 in. high. The leaves are narrowly oblong to lanceolate, obtusely subacuminate at the apex, and rounded at the base; 1 to 2 in. long and ⅓ to ¾ in. broad. The flowers are creamy white, and are arranged in small, dense, terminal corymbs. The fruit is globose, from 1 to 2 in. in diameter, mottled dirty yellow when mature, with thick rind. (See Plate XI.)

This plant is one of the principal sources of the so-called root rubber which is obtained from the bark of the underground stems (rhizomes). It occurs in the French and Belgian Congo, Angola, and Nyasaland, usually growing on sandy plains.

Landolphia parvifolia, K. Schum.—A small much-branched shrub which develops tendrils (modified inflorescences) from the branch forks. The leaves are small, oblong to lanceolate, and subacuminate to subobtuse at the base; ¾ to 1¼ in. long and about ½ in. broad. The flowers are pale yellow or white, in small, dense, subsessile or shortly peduncled corymbs. The fruit resembles a small orange in shape, 1 to 2 in. in diameter, greenish-purple outside, with smooth thick rind.

L. parvifolia is also one of the sources of root rubber. It is found in Angola, Rhodesia, and Nyasaland.

Clitandra orientalis, K. Schum.—A climbing shrub with oblong or oblanceolate leaves, which are 3 to 3¾ in. long

Landolphia Thollonii, DEWÈVRE

Clitandra henriquesiana, K. SCHUM.

PLANTS YIELDING ROOT RUBBER

and 1 to 1½ in. broad, obtusely acuminate at the apex, and acute or subcuneate at the base. The flowers are arranged in dense, compound, axillary and terminal corymbs.

This vine occurs in German East Africa and Uganda, where it is an important source of rubber.

Clitandra Arnoldiana, De Wild., which is found in the Belgian Congo, and *Clitandra elastica*, Chev., occurring in West Africa from the Ivory Coast to Southern Nigeria, are probably varieties of *C. orientalis.*

Clitandra henriquesiana, K. Schum.—An erect shrub, up to 6 in. in height, and much branched from the base. The leaves are lanceolate or oblong-lanceolate, obtusely subacuminate, 1 to 2 in. long and ½ to ¾ in. broad. The flowers are arranged in shortly peduncled, few-flowered axillary cymes. (See Plate XI.)

This plant, which occurs in Angola and Northern Rhodesia, is one of the sources of root rubber.

Growth of Rubber Vines.—The majority of the rubber-yielding vines are very slow growers, and in consequence plants raised from seed require a considerable time before they attain a sufficient size for exploitation. The rate of growth is known to vary widely in the different species, but there is little definite information as to the average age at which the various vines can be tapped.

The results of cultivation experiments in the Belgian Congo indicate that *Landolphia Klainei*, which is one of the quickest-growing vines, may be ready for tapping when about eight years old, whereas it seems probable that the other species of Landolphia and Clitandra indigenous to the country could not be tapped until they are about fifteen years old.

Some interesting particulars have been given by Chevalier and others regarding the rate of growth of *L. Dawei*, which is another quick-growing vine. It is stated that the growth of the seedlings is at first slow, as plants raised in a nursery on good soil only attained a height of 6 in. in six months. Schlechter measured some plants of this species, two and a half years old, which were growing at Soppo in the Cameroons, and found the stems to be 16½ ft. in length, but less than ½ in. in diameter; whilst Preuss records that specimens at Monte-Café in San Thomé, when five years old, had

reached the summits of the supporting trees (over 80 ft.), but he does not give the diameter of the stems. These vines at Monte-Café when seen by Chevalier were twelve and a half years old, and had attained the size of the fully grown vines occurring in the forests of tropical Africa. Two stems which he measured were 18 and 20 in. in circumference at the surface of the soil, and 16 in. at a height of 6 ft.; another measured 18 in. in circumference at 8 in. above the soil, and at 12 in. divided into four branches, each of which was 10 in. in circumference. Chevalier states that none of the other species of Landolphia of which he has had the opportunity of measuring specimens of known age shows such rapid growth as these vines of *L. Dawei* at Monte-Café.

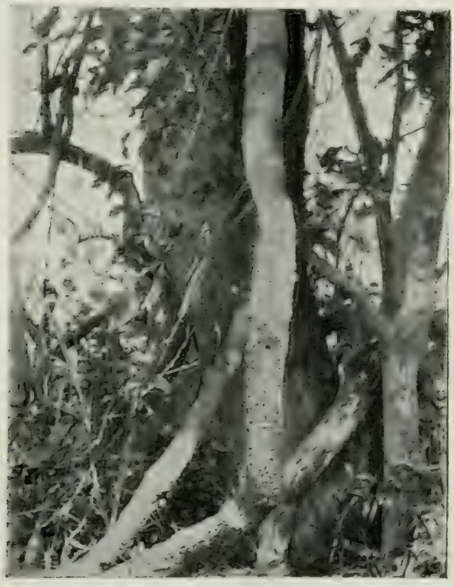
With regard to *L. Heudelotii*, Henry has expressed the opinion that vines growing under the best conditions in the forests of Casamance or the Ivory Coast can be tapped when about eight years old, whereas in the dry regions of the Sudan the vines are not ready for tapping until at least ten years old and the bushes not before the twentieth year.

Experiments with *L. owariensis* in the Gold Coast and with *L. Kirkii* in Nyasaland have shown that both these species grow very slowly under cultivation.

The growth of the plants is also considerably affected by their environment. As already pointed out, certain species develop into either vines or bushes according as they occur in forest or upon open ground, and the vines are also influenced by the conditions under which they grow in the forest. It has been found that growth is most satisfactory when the vines occur on the outskirts of the forest or in open forest, where they have free access to light and air. In dense forest, on the other hand, the growth is retarded and the stems remain exceedingly thin until the vine has climbed to the top of the supporting tree and can expose its leaves to the light, after which the stems begin to increase in thickness; vines growing under these conditions, therefore, develop very slowly.

The rubber vines also differ considerably in vigour of growth, some of them attaining very large dimensions whilst others remain comparatively small. Wild specimens of *L. Klainei* and *L. Dawei*, two of the most vigorous vines, have been recorded with stems 12 in.

Landolphia Vine in the Bahr-el-Ghazal, Sudan, showing Habit of Growth



Landolphia Vine in the Bahr-el-Ghazal, Sudan, showing Large Unhealed Tapping Scars

in diameter at the base and over 300 ft. in length. *L. owariensis* also grows to a large size, but does not quite reach the dimensions of the two species just mentioned.

Collection of the Rubber.—The methods generally adopted by the natives for preparing rubber from these plants may be grouped under the following heads :

(1) *By making incisions in the stems and allowing the latex to coagulate spontaneously in the cuts.*—In a number of cases the latex of rubber vines does not flow freely, and when incisions are made in the stems the latex simply exudes into the cuts and there coagulates. Sometimes the vine is tapped as it hangs on its supporting tree, the native climbing amongst its spreading branches for the purpose ; in other cases the main stems of the vine are severed as high as possible and are then pulled down from the tree, laid along the ground, and tapped in that position. Whichever method is adopted, the native usually makes numerous incisions on every available stem, both large and small, the cuts being often of considerable size.

When the latex is so thick that it only fills the incisions without overflowing, coagulation takes place very quickly, and after a short interval the strips of rubber can be pulled from the cuts. In other instances, however, the latex flows a little more freely for a short time, so that a small quantity runs from the cuts, and in order to prevent the loss of this portion it is collected in a vessel or on a leaf, and is spread out in a thin layer to hasten its coagulation ; or it is received in the hand and smeared on the chest and arms of the collector, where it quickly coagulates. Other methods which are employed in such cases are to cut off a long slice of bark, exposing the wood, and to spread out the latex in a thin layer on the surface thus obtained, or to smear the wound with a coagulant such as a solution of salt or an acid liquid.

The strips of rubber thus obtained are usually made into balls of varying sizes, which are known in the market as "niggers." Generally the balls are formed by the natives at the time of stripping the rubber from the incisions. Sometimes, however, the natives collect the rubber in a loose mass, and afterwards wash it in warm water to remove the fragments of bark as far as possible

before winding the strips into balls. In certain districts the strips of rubber are made into cylindrical or spindle-shaped rolls, instead of into balls.

This method of collecting the rubber is adopted in the case of *L. Heudelotii*, *L. owariensis*, and *L. Kirkii.*

(2) *By collecting the latex in bulk and subsequently coagulating it.*—This method is, of course, only applicable to those vines which yield their latex freely when incisions are made in the stems.

As in the preceding case, the natives either tap the standing vines or first pull the main stems down from the supporting tree and lay them along the ground. Numerous incisions are made in the stems, the latex being collected in cups made from leaves or in receptacles of some other kind and subsequently coagulated. A quantity of scrap rubber can afterwards be collected from the incisions.

Another plan which is adopted in some districts consists in severing the main stem of the vine a short distance above the ground and pulling the vine down from the tree as completely as possible. The stems are then cut into short pieces about 12 in. in length, which are placed upright in a trough and the latex allowed to drain from them as completely as possible. The small quantity of rubber which coagulates on the cut ends of the stems is subsequently collected, and sometimes the rubber left in the bark after the above treatment is extracted by the process of beating described on p. 195.

The latex collected in bulk by any of these methods is coagulated in a variety of ways, the principal of which are the following:

(*a*) *By heat.*—The latex may be coagulated in many cases by the application of heat, either by boiling the latex, by immersing the vessel containing it in boiling water, or by pouring the latex into boiling water. If the latex is coagulated by the application of direct heat, great care should be taken to avoid over-heating the rubber, and the other two methods, when effective, are to be preferred, as they obviate this danger.

The latex of *Clitandra orientalis*, and also of *C. Arnoldiana* and *C. elastica*, is readily coagulated by boiling.

(*b*) *By the addition of various coagulants.*—The coagulants principally used by the natives for the latex of

rubber vines consist of acid juices of plants, or acid decoctions made by boiling certain leaves or fruits with water. In the Belgian Congo the juice of two species of Costus, *C. afer* and *C. lucanusianus*, is employed to coagulate Landolphia latex; whilst in West Africa decoctions of the fruits of the native sorrel (*Hibiscus Sabdariffa*), of the pulp of tamarind fruits (*Tamarindus indica*) or of the leaves of *Bauhinia reticulata* are used for the same purpose. The active coagulant in all these cases appears to be the vegetable acid present in the juice or decoction. Lemon juice or a solution of citric, tartaric, or acetic acid may also be employed for effecting the coagulation. In some cases a solution of salt is used by the natives for the purpose.

This method of adding a coagulant to the latex is adopted for the preparation of the rubber of *L. Dawei* and *L. Klainei*, and also of *L. owariensis* and *L. Heudelotii* when the latex is collected in bulk.

The rubber obtained by these processes of coagulation is treated in different ways in different parts of Africa. In Uganda the freshly coagulated rubber is rolled out into a biscuit or sheet, which is then allowed to dry entire. In the Belgian Congo the rubber is obtained in thin sheets by placing a portion of the freshly coagulated product between leaves and stamping it with the feet. These sheets are afterwards cut up into small cubes or into very thin strips, which are wound into balls of varying sizes and resemble those obtained by collecting the strips of rubber from the incisions. In West Africa the sheets of rubber are cut into thicker strips, which are afterwards rolled up and form what are known as "twists" in the market.

(3) *By the mechanical process of beating the bark.*—This method is exclusively used in the case of the small, bushy forms of Landolphia, Clitandra, and Carpodinus, which only furnish rubber from their underground stems (rhizomes), the product being usually known as "root rubber." It is also employed in some districts of Africa for obtaining rubber from the bark of the stems and roots of the vines.

The process used in the case of the rhizomes is generally as follows:

The rhizomes are dug up and exposed to the sun for

some time in order that the latex may be completely coagulated. They are then cut into lengths and made into bundles, which are carried to a convenient place for treatment. The separation of the bark is effected in different ways in different districts: (1) by beating the dry rhizomes between two stones or upon a block of wood with a wooden mallet; (2) by soaking the rhizomes in water for two or three days and then beating them as above (this procedure facilitates the separation of the bark, but is stated to affect adversely the quality of the rubber obtained); and (3) by stripping off the bark with the aid of a knife. The separated bark is exposed to the sun for several days in order to dry it thoroughly, and is then beaten in a wooden mortar with a pestle of wood, or upon a block of wood with a wooden mallet, or sometimes between stones. By this treatment the bark is reduced to coarse fragments, and the particles of rubber which it contains adhere together and form a loose mass. The beating is continued until as much as possible of the bark has been eliminated from the rubber. The cake of impure rubber, sometimes divided into small pieces, is then placed in boiling water for a short time in order to soften it and is again beaten as before. When a mortar and pestle are employed, boiling water is usually poured into the mortar and the beating continued in the presence of the water. This treatment of the crude rubber with boiling water, followed by further beating, facilitates the removal of the vegetable matter, and the process is continued until rubber of the required degree of purity is obtained. By repeating the operations a considerable number of times, very pure rubber can be prepared by this process; but as a rule the natives only treat the rubber two or three times with boiling water, and consequently the product which they obtain generally includes a considerable quantity of vegetable impurity. The cake of finished rubber is usually cut up into small pieces which are placed in boiling water, and whilst still soft are formed by pressure into balls or cylindrical rolls.

Similar processes to the above are also employed by the natives to prepare rubber from the vines, the bark of both stems and roots being used for the purpose. The practice of digging up the roots of the vines for exploita-

tion in this way leads, however, to the inevitable destruction of the plants. In the case of the species with rhizomes, sufficient of the underground stems are usually left in the ground to ensure the production of new plants; but there is a considerable danger of their extinction if the process is extensively worked by the natives.

A number of machines have been designed for the extraction of rubber from bark by mechanical processes, analogous to those employed by the natives, and some of them give very satisfactory results so far as the yield and quality of the rubber are concerned. Very large supplies of bark are, however, required in order to run an installation of these machines for any length of time. The Guiguet and the Valour machines are the two principal types in use at the present time, and installations of each of these have been tried in different parts of Africa. Such machines can, of course, be used to treat any suitable bark containing a sufficient amount of rubber, and not merely the bark of Landolphia stems.

Yields of Rubber from the Vines.—In considering the recorded yields of rubber from the African vines, it will be convenient to consider the different species separately.

Landolphia Heudelotii.—Chevalier made a careful study of this vine in the French Sudan, and estimated from his experiments in that country, which has a dry climate, that the average yield of dry rubber from a vine which had been previously tapped was about 50 grams per annum, the vine being tapped twice during the year.

In the moister districts, such as Casamance and the Ivory Coast, the yield of rubber is greater than in the Sudan. Experiments by Teissonnier gave the following results:

	Age.	Average yield of rubber per plant.
	years.	grams.
L. Heudelotii bushes . . .	8	73
,, ,, . . .	6	29
,, vines . . .	6	80

Similarly, a series of experiments was conducted at Mangacounda in Casamance by Maury on eight *L. Heudelotii* vines, the oldest of which was stated to be

ten years, and the following yields of rubber were obtained:

	No. of stems tapped.	Yield of rubber. grams.
No. 1	8	94
,, 2	8	48
,, 3	1	8
,, 4	4	11
,, 5	2	6
,, 6	1	3½
,, 7	1	11½
,, 8	3	50½

The total yield of rubber from the eight vines was 232·5 grams, an average of 29 grams per vine. The vines are tapped three times a year by the natives; and if the average yield obtained in the experiments was normal, it would correspond to an average annual yield of about 87 grams per vine.

Later trials made at the experimental garden at Camayenne have shown that 100 to 150 grams of rubber per annum can be regularly obtained in two tappings from *L. Heudelotii* vines when ten to twelve years old; and Yves Henry, the Inspector of Agriculture in French West Africa, has expressed the opinion that eight-year-old vines growing under the best conditions will yield at least 200 grams of rubber per annum.

All these yields of rubber from *Landolphia Heudelotii* were obtained by tapping methods only.

Landolphia owariensis.—A number of experiments to determine the yield of rubber from vines of this species have been made in the Belgian Congo, the rubber being first extracted by tapping or by cutting the stems into short lengths, and subsequently by beating the dried bark.

From a vine seven years old Cranshoff obtained the following results:

	Yield of rubber. grams.
Tapping of oldest stems and primary branches	18
Beating of bark from tapped stems	37
,, ,, ,, untapped stems	8

The total yield of rubber from this vine was, therefore, 63 grams, of which 45 grams were obtained by beating the bark.

An important series of experiments has been made with *L. owariensis* vines at the Botanic Gardens at Eala by M. Seret, the Director, in order to determine the yield of rubber obtainable from them. In these experiments the vines were severed at about 3 ft. from the soil, and the stems cut into pieces from 12 to 20 in. long. The latex was allowed to drain from the pieces of stem and was afterwards coagulated. The portions of stem were collected, dried for three weeks, and the rubber remaining in the bark was extracted by beating. The following table summarises the results which were obtained:

LANDOLPHIA OWARIENSIS VINES

Experiment.	Length of stem treated.	Circumference of stem.	Yield of latex.	Yield of dry rubber from latex.	Yield of dry rubber by beating bark.	Total yield of dry rubber.
	metres.	cm.	cc.	grams.	grams.	grams.
1 . .	12	14 at base	58	8	6	14
2 . .	56	20 to 6	235	57	180	237
3 . .	46	36 ,, 33	696	150	720	870
4 . .	11½	7 ,, 5	—	2	23	25
Totals .	—	—	—	217	929	1,146

It will be seen that in experiments 2, 3, and 4 the yield of rubber obtained by beating the bark was very much greater than that obtained from the latex. In the first experiment, however, the yield of rubber from the bark was less than that obtained from the latex, and an experiment at Bena Dibele gave a similar result, as follows:

Circumference of stem.	Yield of rubber from latex.	Yield of rubber by beating the bark.	Total yield of rubber.
cm.	grams.	grams.	grams.
19 to 16	153	74	227

M. Seret also conducted an experiment on a large *L. owariensis* vine growing in the forest, using (1) the main stem, (2) the branches, and (3) the root. The prin-

cipal stem measured 10·5 metres in length and ranged in circumference from 25 to 18 cm.; the branches which were treated were 27·8 metres in length and the root 4·2 metres. The same method was adopted as in the preceding experiments, and the yields of rubber obtained were as follows:

Portion of vine.	Latex.	Yield of fresh rubber from latex.	Yield of rubber by beating the bark.
	cc.	grams.	grams.
Main stem . .	158	26	135
Branches . .	260	70	250
Roots . . .	20	4	27
Totals .	438	100	412

In this experiment also the yield of rubber from the beaten bark was much greater than the amount obtained from the latex.

M. Seret concluded from the results of these experiments that in the case of *L. owariensis* only a small proportion of the rubber present in the plant can be obtained by cutting the stems into lengths and allowing the latex to drain out, as the latex is usually thick and does not flow freely. Three-fourths of the total rubber usually remains behind in the bark, from which, however, it can be extracted by beating. It may be noted that the *L. owariensis* vines used in these experiments all put out new shoots from the portion of the stem which was left in the ground.

In illustration of the yield of rubber obtainable by tapping *L. owariensis* vines, the results of an experiment made by the author in the Bahr-el-Ghazal Province of the Anglo-Egyptian Sudan may be quoted. The trial was conducted during the dry season with a large vine of *L. owariensis*, var. *tomentella*, Stapf, which had not been tapped during the previous year. The incisions were made with a V knife, 8 in. apart, and did not extend round more than one-third of the circumference; no stem less than 6 in. in circumference was tapped. Ninety-six incisions were made on the vine, and the yield of latex was 280 cc., or just under 3 cc. per incision, the maximum yield from an incision being 5 cc. The total yield of

dry rubber, including that which coagulated in the cuts, was 172·8 grams, *i.e.* a little over 6 oz., equal to 1·8 gram per incision. Other vines which were tapped gave lower yields than this; but the majority of them had been very severely tapped during the preceding season, and were therefore not in good condition.

Landolphia Gentilii.—This vine is very closely allied to *L. owariensis*, and a tapping experiment conducted at Bena Dibele by M. Seret gave the following results, which are very similar to those already recorded for *L. owariensis*:

Circumference of stem.	Yield of rubber from latex.	Yield of rubber by beating the bark.	Total yield of rubber.
cm.	grams.	grams.	grams.
19 to 16	290	408	698

Landolphia Klainei.—M. Seret obtained the following results from a specimen of this vine at Bena Dibele:

Circumference of stem.	Yield of rubber from latex.	Yield of rubber from bark.	Total yield of rubber.
cm.	grams.	grams.	grams.
15 to 14	184	41	225

In this case, therefore, the bulk of the rubber was obtained from the latex, the bark yielding less than one-fifth of the total.

Landolphia Kirkii.—It is stated that *Landolphia Kirkii* vines in Nyasaland furnish on an average about 1 oz. of rubber per annum, the yield depending principally on the age of the vine. As much as 7 oz. of rubber have been obtained in a year from specially large vines.

According to experiments made by Capt. Silveira Machado in Portuguese East Africa, vines belonging to this species give an average yield of about 28 grams at one tapping during the dry season, and 120 grams during the wet season. Experiments made by the Mozambique Company indicate that the yield of rubber varies from 30 to 200 grams per vine.

Landolphia Dawei.—This vine furnishes a large yield of rubber, but no results of tapping experiments are available. Dawe has stated that in Uganda vines of this species will give, when carefully tapped, much more than 8 oz. of dry rubber per annum; whilst Chevalier, from his experience of the vine in West Africa, considers that when ten years old it will yield 500 grams (1·1 lb.) of dry rubber per annum.

In Uganda a large vine will give as much as a quart of latex at one tapping, and, according to the natives, the vines can be tapped three times a year without injury.

Clitandra Arnoldiana.—The yield of rubber obtainable from this vine was also investigated by M. Seret at Eala by the same method as was adopted in the case of the Landolphia vines. The vine was severed at about 3 ft. above the soil and detached from the supporting tree; the stem was then cut into pieces and the latex allowed to drain out as completely as possible; afterwards the stems were dried, the bark stripped off, and the rubber extracted by beating. The results obtained are summarised in the following table:

Experiment.	Length of stem treated.	Circumference of stem.	Yield of latex.	Yield of dry rubber from latex.	Yield of dry rubber from bark.
	metres.	cm.	cc.	grams.	grams.
1 . .	13	23 to 14	290	52	nil.
2 . .	12	24 at base	230	45	2
3 . .	56	15 to 4	225	35	not stated
4 . .	10	24 ,, 15	150	23	nil.
	120	13 ,, 5	335	38	
5 . .	23	15 at base	122	22	nil.

Further experiments were made on cultivated vines growing at Eala and at Bamania with the following results:

Age.	Length of stem treated.	Circumference of stem.	Yield of latex.	Yield of dry rubber from latex.	Yield of dry rubber from bark.
years.	metres.	cm.	cc.	grams.	grams.
7	30	9 at base	—	3	nil.
12	—	—	120	26	not stated

Another experiment was conducted with a large forest vine, using both stems and roots. The principal stem was 17½ metres long and from 30 to 25 cm. in circumference; the branches were 106½ metres in length and from 20 to 4 cm. in circumference; the root was 9 metres long and from 25 to 7 cm. in circumference. This vine was treated in the following manner: (1) all the parts were cut into pieces from 12 to 20 in. long and the latex allowed to drain out; (2) two days afterwards about 4 in. was cut from the larger end of each piece, when a fresh flow of latex was obtained; (3) two days later a circular incision was made in the middle of each piece. The following yields of latex and rubber were obtained:

Portion of vine.	(1)		(2)		(3)	
	Latex.	Fresh rubber.	Latex	Fresh rubber.	Latex.	Fresh rubber.
	cc.	grams.	cc.	grams.	cc.	grams.
Principal stem . .	812	230	?	100	84	20
Branches . . .	1,252	330	460	95	80	16
Root	438	55	46	5	nil.	nil.
Yield of fresh rubber .		615		200		36

The total yield of fresh rubber was therefore 851 grams, and this furnished 720 grams of dry rubber. No rubber was obtained by beating the bark.

It would appear from these experiments that the latex of *Clitandra Arnoldiana*, unlike that of *Landolphia owariensis*, drains almost completely from the cut stems, and that practically no rubber can be subsequently obtained by beating the bark.

It may be mentioned that four of the five vines used in the first experiments were found to be dead about two months after being cut; the fifth had developed some new shoots, but not from the cut stem, but from some small branches which had been left intact.

The results of an experiment to determine the yield of rubber obtainable from *Clitandra Arnoldiana* by tapping may also be given. At the first tapping the vine furnished 270 cc. of latex, which yielded 100 grams

of fresh rubber ; about a year later it was again tapped and gave 240 cc. of latex, from which 87 grams of fresh rubber were obtained. It was proposed to tap this vine again at the end of another year, but it died during the interval, notwithstanding the fact that the tappings had been very carefully performed. M. Seret concluded from this experience that *C. Arnoldiana* vines tapped by the native method would be inevitably killed, and he suggested that the best method of exploiting these vines would be to tap them at first, and then, after an interval of time to be determined, to cut them down and extract the whole of the rubber from the stems and root by beating the bark.

Yields of Rubber ("Root Rubber") from Rhizomes. *Landolphia Thollonii.*—A series of experiments was conducted by the Government of Angola with rhizomes of *L. Thollonii* collected in the district of Lunda, and the results obtained are summarised in the following table :

RHIZOMES OF LANDOLPHIA THOLLONII

	I	II.	III.
	kilos.	kilos.	kilos.
Weight of the rhizomes . . .	14	14	14
,, ,, bark	7·500	7·500	7·400
,, ,, dry bark . . .	6·500	6·500	6·500
,, ,, powder	4	4	4
,, ,, impure rubber . .	2·500	2·500	2·500
,, ,, rubber after 1st washing .	2·450	2·400	—
,, ,, ,, ,, 2nd ,, .	2	2	1·889
,, ,, ,, ,, 3rd ,, .	1·500	1·480	1·800
,, ,, ,, ,, 4th ,, .	1·389	1·380	1·240
,, ,, ,, ,, 5th ,, .	1·175	1·300	1·075
,, ,, ,, ,, 13th ,, .	1·043	0·840	0·973
Percentage of rubber from rhizomes .	7·4	6·0	6·9
,, ,, ,, dry bark .	16·0	13·0	15·0

The rubber obtained in these experiments is stated to have been very much purer than that prepared by the natives, who generally only wash the product two or three times. After the third washing the average yield of rubber from 14 kilograms of rhizomes was 1·593 kilograms, equivalent to 11·4 per cent., as against the final yield of 6·0 to 7·4 per cent. obtained in the experiments.

Baudon records that in the French Congo 20 kilograms of the rhizomes of *L. Thollonii* furnished 1·120 kilogram of marketable rubber, a yield of 5·6 per cent., and Guynet states that in the Belgian Congo the average yield of rubber from the rhizomes is 5 per cent.

Landolphia chylorrhiza.—Geraldes records the following results of experiments conducted in Angola to determine the yield of rubber obtainable from the rhizomes of this plant by beating the separated bark :

Diameter of the rhizomes . . .	5 to 9 mm.
Ratio of weight of dry bark to weight of dry rhizomes	64·77 per cent.
Percentage of clean rubber obtained from dry rhizomes	7·5 ,, ,,
Percentage of clean rubber obtained from dry bark	11·6 ,, ,,

The composition of the clean dry rubber, excluding the moisture and vegetable matter present, was as follows :

	Per cent.
Caoutchouc	94·31 to 95·86
Resin and colouring matter .	3·50 ,, 4·14

In Angola the yield of rubber generally obtained by the natives from *L. chylorrhiza* is from 10 to 12 per cent. of the weight of the rhizomes.

Cost of Collection.—There are little data available regarding the cost of collecting rubber from Landolphia vines by the native process, but M. Seret has given the following particulars on this point in the case of two of his experiments at Eala, which have already been referred to.

One hundred and fifty grams of rubber were obtained from a *Landolphia owariensis* vine by coagulating the latex obtained by cutting the stem into pieces, and 720 grams by beating the bark. All the operations involved in the preparation of the 150 grams of rubber, including the time spent in going to the place of collection, were performed by two men in 4½ hours, or 9 hours' labour. The

beating of the bark necessitated 32 hours' labour, making a total of 41 hours. This labour was valued at fr. 1·64, and the cost of collecting a kilogram (2·2 lb.) of rubber on this basis would be fr. 1·88.

In another instance a *Clitandra Arnoldiana* vine furnished 851 grams of rubber, of which 615 grams were obtained by the first operation, 200 grams by the second, and 36 grams by the third (see p. 203). Three men worked for 5 hours in obtaining the 615 grams of rubber; two men for 4 hours in obtaining the 200 grams; and two men for 3 hours in obtaining the 36 grams. This represents a total of 29 hours' labour, and on this basis it was estimated that the cost of collection of a kilogram of the rubber would be about fr. 1·40.

Baudon has given the following data regarding the time taken by a native in the French Congo to treat 20 kilograms of the rhizomes of *Landolphia Thollonii*:

	Hours
Collection of the rhizomes . .	8
Beating	20
1st washing and beating . .	4
2nd ,, ,, . .	4
Total	36

In this experiment the native, by the expenditure of thirty-six hours of labour, obtained 1·120 kilogram of marketable rubber.

Improved Methods of Exploiting Rubber Vines.—Much discussion has taken place on the question of the best method of exploiting rubber vines, and many attempts have been made to improve the native methods of collection so as to prevent the destruction of the plants. The problem, however, presents many difficulties, principally owing to the habit of growth of the vines which renders them much more difficult to deal with than rubber trees, and no general agreement as to the most satisfactory method of treatment has been reached.

The two principal systems employed by the natives have been already referred to, viz.: (1) tapping the vines

either as they hang on the trees or after detaching the branches as completely as possible from their supports and laying them on the ground; and (2) severing the vines at or near the ground, cutting up the stems into short lengths and allowing the latex to drain out, and then in some cases extracting the rubber left in the bark by a process of beating. Formerly the second method of cutting down the vines was not regarded with favour, as it was considered to lead to the destruction of the plants; and in the Belgian Congo this system of exploitation was prohibited as far as possible, only the tapping method being allowed.

The chief objections to the native methods of tapping are as follows: (1) the number of incisions is excessive and they are made on every available stem, even the smallest; (2) the incisions are usually of considerable size, frequently almost encircling the stem, whilst in other cases long slices of bark are removed, exposing large areas of wood; such incisions never heal completely and thus afford an easy entry for insect and fungoid pests; and (3) the vines are usually retapped before the previous incisions have healed. As a result of such treatment the vitality of the plant is affected, and if the tapping is continued, the vine is speedily killed, especially in those cases in which it has been pulled down from its natural position and laid on the ground. Attempts have accordingly been made to improve the methods of tapping employed by the rubber collectors, so as to ensure that the vines shall not be tapped within 30 in. of the base; that stems less than 6 in. in circumference shall not be tapped; that only narrow incisions shall be made, 8 to 10 in. apart on one side of the stem, and shall not extend more than one-third or half-way round the stem; that the incisions shall not expose the wood; and that the vines shall not be retapped until the previous incisions have healed. It has been sought to attain these objects by the introduction of tapping regulations, which, however, are difficult to enforce without a very large staff of Forestry officers, and by the instruction of the natives in rational methods of tapping either in "rubber schools," such as have been established in French West Africa, or by travelling instructors. Considerable improvement has been effected in French West Africa as the result

of the training of the rubber collectors, and the vines are now much more carefully looked after and tapped than formerly. From the evidence available, it seems probable that certain species of rubber vines, *e.g. Landolphia Heudelotii* and *Landolphia owariensis*, could be tapped repeatedly without permanent injury if the above-mentioned precautions were rigorously observed, but it is almost impossible to ensure this in the forests. Experiments made on *L. owariensis* vines in the Bahr-el-Ghazal Province of the Sudan showed that narrow incisions made with a triangular tapping-knife yielded as much rubber as the larger cuts employed by the natives, and that such incisions healed completely within five months.

It is contended, however, by some authorities that tapping is an entirely wrong method of exploiting rubber vines, as, in their opinion, no matter how carefully the tapping is done, the vines will inevitably be killed by the treatment. They maintain that the alternative native plan of cutting down the vines, draining the latex from the cut stems, and finally extracting the rubber from the dried bark, is far preferable to any tapping process. The advantages claimed for this procedure are that it gives a larger yield of rubber than can be obtained by tapping, and that the vines are not killed, but put out new shoots from the basal portion of the stem. It is stated that these shoots can be treated in the same manner in two or three years' time, as the rubber they yield is much superior in quality to that furnished by seedling vines of the same age. In using this method, care should be taken to cut the vines at least 30 in. above the ground so as to leave a good "stool" for the development of new shoots.

It is not possible at present to express a definite opinion as to the effect of cutting down the vines on a large scale, but the method has come into considerable favour recently, and has been adopted in the Belgian Congo instead of the tapping process. It is no doubt true that the native methods of tapping usually destroy the vines, and probably certain species of vines, even if carefully tapped, are very liable to be killed by the treatment, as in the case of M. Seret's experiments on the tapping of *Clitandra Arnoldiana* (see p. 203). It must, however,

not be overlooked that M. Seret also found that *C. Arnoldiana* vines died after being cut, so that it is possible that vines which will not bear careful tapping will also be killed by cutting. This and other points respecting the merits of the two methods will, no doubt, be decided by the results obtained in the Belgian Congo; but by the time a decision is reached it is possible that the rubber vines will have ceased to be of much interest as sources of rubber.

Cultivation of the Vines.—Considerable attention was formerly devoted in several parts of tropical Africa to the possibility of forming plantations of the indigenous rubber vines, and in the Belgian Congo in particular large numbers of the vines were planted out in the forests. It has been found, however, that in general the enterprise is not very successful, owing to the facts that the vines are of very slow growth, that they require much attention in the young state so that the cost of upkeep is considerable, that they are much more difficult to exploit than rubber trees, and that the returns from the vines even under the best conditions are less than from rubber trees. Some authorities still advocate the planting of rubber vines in tropical Africa in preference to trees, as they allege that the failure in the past has been due to the neglect of certain essential precautions; but this view is not widely held, and even in the Belgian Congo the planting of vines, except on a small scale for experimental purposes, has now been definitely abandoned in favour of the cultivation of rubber trees. In view of the above facts and of the success which has attended the cultivation of rubber trees in tropical Africa, it is extremely improbable that any further attempts will be made to plant rubber vines on a large scale, certainly not in any of the British Colonies and Protectorates. It is consequently unnecessary here to describe in detail the methods employed, but it may be stated that the usual procedure was to raise the vines from seed in nursery beds and to plant out the seedlings at the base of trees in the forest. Some of the species do not stand transplanting very well, and in these cases the plan was tried of sowing the seed in prepared mounds of soil at the places the vines were to occupy in the forest. This method was, however, not very successful, as the seedlings

require a considerable amount of protection in the young state, which is difficult to give when they are scattered through the forest. Better results were obtained by sowing the seed in baskets made of some fibrous material, and, when the vines were a year old, planting them out without removing the basket, so as to avoid disturbing the roots.

It has been pointed out already that the stems of vines growing in dense forest only increase in thickness very slowly, and in consequence of this fact more open situations were latterly chosen for planting purposes, in order that the young vines might be exposed to light and air. A further modification, which is probably the best arrangement, is to plant the young vines in the open at the same time as quick-growing trees, such as species of Albizzia, which are to serve as supports for the plants. In this way the vines and trees grow up together and the maximum development of the vines is obtained.

Full information on the subject of the cultivation of rubber vines will be found in the *Manuel pratique de la culture et de l'exploitation des essences caoutchoutifères indigènes et introduites au Congo Belge.**

Composition of Vine Rubbers.—The rubber obtained from many of the vines is of excellent quality if carefully prepared, and specimens in the form of biscuits or sheet frequently contain over 90 per cent. of caoutchouc and low percentages of resin, protein, and ash. The amount of resin usually ranges from 4 to 10 per cent. according to the species, and in Landolphia rubbers the percentage of protein is almost always less than 2 per cent. and frequently less than 1 per cent. Specially prepared Landolphia rubber contains less protein than any other variety of rubber.

The ball rubber as collected by natives, and also the "root rubbers," always contain more or less vegetable impurity in the form of fragments of bark, but in the best qualities this is reduced to a minimum.

The "paste" or "flake" rubbers prepared from certain vines are of very resinous nature and consequently of low value.

* Brussels: Imprimerie A. Lesigne, 27, rue de la Charité, 1909.

The following analyses, made at the Imperial Institute, illustrate the composition of a number of different specimens of vine rubber:

Species of vine.	Country.	Description of rubber.	Composition of dry washed rubber.			
			Caoutchouc.	Resin.	Protein.	Ash.
			Per cent.	Per cent.	Per cent.	Per cent.
Landolphia Heudelotii	Gambia	Ball	91·3	5·9	1·4	1·4
,, ,,	Senegal	Sheet	93·8	5·9	0·1	0·2
Landolphia owariensis	Gold Coast	Ball	93·8	4·9	0·9	0·4
,, ,,	,,	Biscuit	90·6	6·2	0·9	2·3
,, ,,	Bahr-el-Ghazal, Sudan	,,	93·6	4·4	0·5	1·5
,, ,,	,,	,,	94·1	5·7	trace	0·2
,, ,,	,,	Sheet	93·7	5·6	0·4	0·3
Landolphia Kirkii .	E. Africa Protectorate	Ball	90·8	7·5	1·0	0·7
,, ,,	Natal	,,	87·4	10·9	1·3	0·4
,, ,,	Northern Rhodesia	,,	86·0	10·8	2·1	1·1
,, ,,	Portuguese E. Africa	,,	92·3	5·9	1·3	0·5
Landolphia Dawei .	Uganda	Sheet	92·4	6·6	0·8	0·2
,, ,,	,,	Biscuit	91·1	7·7	0·9	0·3
Clitandra orientalis	,,	Sheet	84·8	6·4	8·5	0·3
Clitandra elastica .	Southern Nigeria	Biscuit	92·2	4·1	3·3	0·4
Carpodinus hirsuta	Northern Nigeria	Paste	9·5	88·8	1·2	0·5

CHAPTER XIII

THE CENTRAL AMERICAN RUBBER TREE, *CASTILLOA ELASTICA*, CERV.

Species of Castilloa.—The rubber trees which occur wild in Central America belong to the genus Castilloa of the natural order Urticaceae, and until recently it was customary to regard the majority of the trees as *Castilloa elastica*, the original species described by Cervantes in 1794. It was known, however, that the trees showed some variations in characters, for in 1885 Hooker, in a paper " On the *Castilloa elastica* of Cervantes and some allied rubber-yielding plants," * had drawn attention to the existence of three well-marked varieties of Castilloa from Central America which differed in certain respects from the typical *C. elastica*, but he did not assign new specific names to these forms. Subsequently Koschny studied the Castilloa trees of Costa Rica and came to the conclusion that there were four distinct varieties, which he named *C. alba*, *C. nigra*, *C. rubra*, and *C. Tanu*, the first three of these being rubber-yielding trees. These views as to the existence of different forms of Castilloa have since been fully confirmed, and it is now recognised that the Castilloa trees growing in different districts of Central America vary not only in botanical characters, but also in the yield of rubber which they furnish. It has been stated that nine fairly distinct forms of Castilloa can be distinguished in Mexico alone, some of which are specially suited to certain climatic conditions, so that plants raised from seed obtained from the Castilloa trees growing on the Atlantic Coast, where there is an almost continuous rainfall, will not succeed on the Pacific coast, where there is a distinct dry season of about six months.

* *Transactions of Linnean Society*, vol. ii. pt. 9, p. 209.

These varieties of Castilloa have been carefully studied recently by several botanists, notably by Cook and Pittier of the United States Department of Agriculture, with the result that a number of them have been described as separate species. Pittier, the most recent investigator, is of opinion that the following ten species of Castilloa may be provisionally recognised: *C. elastica*, Cerv.; *C. costaricana*, Liebm.; *C. fallax*, Cook; *C. lactiflua*, Cook; *C. nicoyensis*, Cook; *C. panamensis*, Cook; *C. guatemalensis*, Pittier; *C. daguensis*, Pittier; *C. australis*, Hemsl.; and *C. Ulei*, Warb.

The first eight species are natives of Central America; *C. australis* occurs in Peru, and *C. Ulei* in the Amazon valley. In addition to these forms there is another Central American species described by Hemsley as *C. Tunu*, upon which Pittier is at present unable to pronounce a definite opinion.

Pittier states that the ten forms mentioned above are perfectly distinct and characteristic, but he admits that further study may reduce some of them to the position of subspecies or varieties.

The existence of these different species or well-marked varieties of Castilloa, which require different climatic conditions and furnish varying amounts of rubber, is a point of considerable importance to planters, and care should be taken to select for cultivation the particular form of tree most suited to the local conditions of climate and soil. Pittier has stated that for semi-arid districts with well-characterised dry and rainy seasons he would recommend *C. lactiflua* of the Soconusco district of the State of Chiapas in Southern Mexico; *C. nicoyensis* from the dry Pacific slopes of the Nicoya Peninsula in Costa Rica; and probably *C. panamensis* from Panama. For districts where rain predominates, he considers that *C. costaricana* from the humid Atlantic slopes of Costa Rica and *C. elastica* are the most suitable. Experiments with the different varieties are being conducted in Mexico in order to determine their relative value as sources of rubber.

In the following account it will be convenient to regard the name *Castilloa elastica* as including the different forms of Castilloa trees occurring in Central America.

Botanical Characters.—*Castilloa elastica* is a large tree

which, under favourable conditions, may attain a height of 160 to 180 ft. with a trunk 12 or 13 ft. in circumference at 3 ft. from the ground. The bark is usually rather smooth, soft, and light grey, though there is some variation in the colour. The young branches are densely covered with greenish-yellow or brown hairs. The leaves are very large, ranging from 12 to 20 in. in length and from 4 to 7 in. in breadth, opposite, and hang from the branches in two pendant rows; they are light green, oblong, cordate at the base, and the veins are very prominent below. The under surface of the leaves is covered with greenish-yellow hairs, which are especially numerous on the midrib and larger veins, and project in little tufts from the margin; the upper surface is much less hairy and darker in colour. The flowers are male (staminate) and female (pistillate), and both forms usually occur on the same tree, although young trees frequently bear only male flowers. The fruits, which occur in clusters, are orange-coloured and fleshy, each containing an ivory-white seed, $\frac{1}{4}$ to $\frac{1}{3}$ in. in diameter, with a very thin papery seed-coat. The seeds only retain their vitality for a short time.

A striking peculiarity of *Castilloa elastica* is the production, during the early stages of growth, of temporary deciduous branches, which, although not more than 1 in. in diameter at the base, are often 10 to 12 ft. in length. These branches drop off after a time, being detached from the trunk by the rupture of a special layer of tissue at the base. As a general rule, the permanent branches do not develop before the third or fourth year.

Distribution.—*Castilloa elastica* is found growing wild in Mexico south of 22° N. latitude, and thence extends through all the States of Central America into Colombia; it also occurs on the western slopes of the Andes in Ecuador and Peru.

In Mexico the rubber area includes the States of Vera Cruz, Oaxaca, Chiapas, Tabasco, and Campeche, but only a comparatively small area of this territory is actually suitable for the cultivation of the tree. During recent years very large plantations of Castilloa trees have been formed in Southern Mexico, particularly in the Soconusco and Palenque districts of the State of Chiapas.

Castilloa trees are abundant in certain districts of

British Honduras. According to Morris, they occur on what are known as the Cohune ridges, especially along the banks and in the valleys bordering Mullin's river, Sittee river, and the Rio Grande in the south, and along the Sibun river and the upper waters of the Belize river in the west. The trees are also being cultivated on a small scale in the Colony.

In the States of Central America, Castilloa trees occur on both sides of the mountain chain, and small plantations have been established in most of the countries.

In Colombia the trees are abundant along the valley of the Magdalena river and are also being cultivated. Plantations have been established, too, near Guayaquil in Ecuador.

Castilloa trees have been introduced into several of the British West Indian Islands and have been found to grow well. In Trinidad and Tobago especially large numbers of the trees have been planted, and are now furnishing supplies of rubber of good quality. In Southern India and Ceylon the tree has also been grown successfully, but in East and West Africa it has proved to be extremely susceptible to the attacks of boring beetles.

The Castilloa trees occur naturally at low elevations, being seldom found higher than 2,000 ft. above sea level. They are met with most frequently on the banks of rivers or streams, and on moist plains where there is good drainage ; they cannot be grown successfully on swampy land, nor on a stiff, clay soil. In a wild state Castilloa does not thrive in the dense forest, but prefers more open situations, where it occurs in small groups.

Native Methods of Collecting the Rubber.—The native collectors do not, as a rule, tap trees less than 25 in. in circumference at 3 ft. from the ground, as they consider that the yield from smaller trees is not remunerative. The incisions are made with the native cutlass or machete, and the system of tapping varies in the different districts. The following are the principal methods employed :

(1) Single oblique incisions are made at an angle of about 45° one above the other and from 2 to 3 ft. apart ; the cuts usually extend about three-fourths round the tree. The latex flows to the lower end of the incisions and then runs down the trunk, being collected at the base

in a calabash or in a cavity in the soil lined with a large palm-leaf. Further incisions are made between the original series or across them, with the result that the trunk ultimately presents a very scarred appearance.

(2) Large V-shaped incisions are made about 3 ft. apart, the two cuts forming the V extending nearly round the trunk. A small piece of bent iron or a leaf is usually inserted in the bark at the base of the V in order to serve as a spout for directing the latex into a vessel placed below.

(3) Large spiral incisions extending right round the trunk are sometimes employed.

Formerly many of the trees were cut down in order to obtain the rubber.

The objections to the native methods of tapping are that the incisions are made much too deeply, penetrating the wood in nearly every case ; that the trees are tapped too frequently ; and that the whole of the trunk is tapped, the higher portion being reached by means of rough ladders. This severe treatment has resulted in the destruction of many of the wild trees.

Various methods are employed by the natives of Central America for the coagulation of Castilloa latex.

In Mexico coagulation is brought about by adding to the latex an infusion of the "Morning Glory," or "Moon" vine, *Ipomoea Bona-nox*, L. (*Calonicticn speciosum*).

The stems of this plant are bruised and allowed to stand in water for a short time ; the liquid thus obtained quickly coagulates the latex. The rubber prepared by this method is made into large slabs or cakes, which are very porous and retain in their cavities a large amount of the dark mother-liquor of the latex. This liquid contains a considerable percentage of protein and is consequently liable to undergo fermentation with the development of a very objectionable odour.

Another method which has been used in Mexico is to spread a thin layer of latex on the large leaves of a species of Calathaea ; this is allowed to dry in the sun and then a fresh layer of latex is added, the process being repeated until a sheet of rubber about $\frac{1}{4}$ in. thick is obtained. Two of the leaves then have their rubber-covered surfaces pressed firmly together, when the rubber adheres to form a single sheet, from which the leaves can be easily stripped.

Other sheets are added in the same way until a cake of rubber of sufficient size is obtained.

In British Honduras the juice of the "Moon" vine is also used to coagulate Castilloa latex, and the rubber is made into cakes, which are pressed in order to remove as much of the liquid as possible.

The natives also coagulate Castilloa latex by the addition of solutions of alum, wood ashes, or soap; by boiling; or by allowing it to stand in holes in the ground until coagulation occurs.

In certain districts of Central America the latex of the Castilloa trees does not flow freely, but coagulates in the incisions. In these cases the rubber is collected in the form of "scrap."

Much of the Castilloa rubber obtained by the preceding methods is of inferior quality, owing to defective preparation, and consequently realises a comparatively low price in the market.

Cultivation of Castilloa Trees.—It has been mentioned already that very large plantations of Castilloa trees have been established during recent years in several countries, particularly in Mexico, and a short account of the methods of cultivation and of preparing the rubber may be given.

The trees are usually grown from seed, but they can also be easily raised from cuttings. As the seeds quickly lose their germinating power they require to be specially packed for transport, the most favourable conditions being that they should be kept sufficiently moist to prevent loss of vitality without inducing actual germination. Trees from three to four years old are stated to give the best seed for planting purposes.

In the early experiments the seeds were sown in nurseries, and the seedlings transplanted when they were four to six months old or when they had attained a height of 10 to 12 in. Sometimes, however, the young plants were not moved from the nurseries until they were twelve months old, when they were usually from 5 to 12 ft. high. In the latter case the roots were cut off 5 to 6 in. below the surface of the soil and the stem was reduced to 3 ft.; the stumps thus obtained were then planted in the required positions.

On the Mexican plantations, however, it is now customary to sow seeds "at stake," that is, in the position

which the trees are to occupy, as by this means transplanting is avoided and the growth of the seedlings is not checked. When this plan is adopted the land is cleared and staked according to the distances at which the seeds are to be planted, *e.g.*, 6 by 6 ft., 5 by 10 ft., 9 by 9 ft., 6 by 12 ft., etc. Six to ten seeds are then sown in small raised heaps of soil at each stake. The time of sowing should be chosen so as to avoid a period of drought during the early stages of development, and in situations where there is a distinct, dry season, the plants should be well established before the rains are over. The seedlings are carefully examined during the first six months, and at least half of them are removed, leaving the best specimens. This thinning out is continued so that at the end of the second year only a single plant is left at each stake. Further thinnings should take place from time to time as the trees develop, until at the end of the sixth year only about 400 selected trees remain per acre. In some instances the trees, one at each stake, are allowed to grow until the end of the fifth year, when the best 400 in each acre are selected, and the rest are tapped to death and cut out during the next year. Sometimes, however, the thinning-out process is not properly carried out, and it is stated that on some estates in Mexico there are over 1,000 eight-year-old trees per acre.

Three different methods have been tried in cultivating Castilloa trees. In the first experiments the seedlings were planted out under shade, but it was found that, although the growth in height was rapid under these conditions, the increase in the thickness of the trunk was very slow, and moreover the trees were generally liable to disease.

Planting the trees under partial shade has also been tried. In this plan a few high trees are left standing when the ground is cleared for the plantation, in order to afford some shelter during the dry season, when the Castilloa trees have shed their leaves and are exposed to the scorching sun. This method approximates more nearly than the first to the conditions under which Castilloa trees occur naturally, and it has given good results on some plantations, especially where the soil is liable to become hard and baked if exposed to the sun.

The third method is to sow the seeds at stake in the

open, the requisite amount of shade being obtained by planting the trees sufficiently closely to shelter one another. This method appears to give the most satisfactory results and it is now generally adopted in Mexico.

The question as to the best distance at which Castilloa trees should be planted has given rise to considerable discussion. It has been found that if the trees are planted too closely their growth is checked and the development of the stems interfered with as soon as the roots of the adjacent trees meet. On the other hand, if the trees are placed so far apart that they do not afford each other shade, their growth is stunted and the sun scorches and dries up the bark. The method of planting the trees closely at first and subsequently thinning-out, as described above, obviates both these drawbacks and at the same time affords an opportunity for a careful selection of the permanent trees. It is claimed that with proper management the temporary trees will yield sufficient rubber, before the permanent trees are tapped, to make the plan remunerative.

Tapping of Cultivated Trees.—The method most commonly adopted on the Mexican plantations for tapping Castilloa trees is a system of large V incisions, which are sometimes connected by a vertical channel. The V incisions are made from 12 to 18 in. apart and usually extend round three-fourths or so of the circumference of the trunk ; in the case of mature trees the tapping is carried to a height of about 30 ft., light ladders or slings being used when making the higher incisions. The latex is collected in cups placed at the base of each V incision, or, if a connecting vertical channel is made, in a single cup at the base of the tree. Sometimes spiral incisions are used instead of V cuts.

The half-herringbone system has also been tried in Mexico, but has not been generally adopted. One-half of the tree was tapped at a time, the oblique incisions being made 18 in. apart and connected by a shallow vertical channel. The second half of the tree was treated in a similar manner when the first incisions had healed.

In Tobago a system, introduced by Smith, has been adopted in which a large number of small incisions are made in the trunk by means of a chisel with a specially

thin cutting edge about $1\frac{1}{2}$ in. wide. The incisions are arranged in vertical rows about 4 in. apart, the distance between the cuts in each row being about 12 in.; the tapping extends round the entire circumference of the tree and is carried to a height of 6 ft. or more. The latex runs down the stem and is collected in a calico apron fixed round the base of the tree.

The latex flows from the cuts for periods ranging from twenty minutes to two hours, and no further yield is obtained by reopening the incisions. The latter practice has in fact been found to be fatal to Castilloa trees. The trees may be tapped any time during the year except in the dry season, the length of which varies in the different districts. At La Zacualpa the tapping period lasts for ten months of the year, from April to January.

Until recently, cultivated Castilloa trees were not tapped in Mexico until they were seven years old, but it has been found that four-year-old trees which have attained a girth of 15 in. can be lightly tapped without injury. The young trees are first tapped to a height of 6 ft. only and the incisions are gradually carried higher as the trunk increases in girth. Mature trees are tapped three times a year.

Preparation of the Rubber.—The rubber is prepared on the plantations by the native method of coagulating the latex with an infusion of the stems of the "Moon" vine, or by allowing the latex to cream, or by spinning it in a centrifugal machine.

Creaming.—Castilloa latex "creams" very readily when diluted with water and allowed to stand, and this behaviour affords an easy method of preparing the rubber. The latex is first strained by means of a centrifugal strainer, and is then diluted with water and poured into settling tanks. The diluted latex is allowed to stand until the rubber globules have completely separated as a cream, and the clear serum is then run off as completely as possible by means of a pipe at the bottom of the tank. The cream is stirred up with a fresh supply of water and allowed to stand again until complete separation has occurred. This treatment may be repeated several times, and finally the cream of rubber globules is separated and made to coagulate either by pressure or by working it with wooden paddles. The freshly coagulated rubber

is then converted into crêpe by means of a washing machine.

On many estates in Tobago the cream of rubber globules is poured on to wet cotton sheets, stretched in a frame, and allowed to drain, when a sheet of rubber is obtained which is subsequently stripped from the cloth.

Centrifugal Methods.—Castilloa latex can be quickly coagulated by spinning it in a centrifugal machine. On many of the estates in Mexico the "Empire" cream separator is used for the purpose, and the rubber is obtained in the form of a solid cone, which can afterwards be converted into sheet or crêpe if desired. Smith's centrifugal machine which is used in Tobago enables the rubber to be prepared in the form of sheets.

Yield of Rubber from Castilloa Trees.—In considering the question of the yield of rubber from Castilloa trees, it must be borne in mind that the different species or varieties of the tree occurring in Central America are stated to vary widely in the amount of rubber which they furnish, so that the results obtained from trees in a particular locality cannot be taken, without further investigation, to represent the yield from trees growing in other districts.

The information available regarding the amount of rubber obtainable from wild Castilloa trees is very incomplete, and it is not possible to give any trustworthy figure for the average annual yield per tree. It has been recorded that large forest trees have yielded as much as 10 to 20 lb. of rubber, or even more, at a single tapping, but it is probable that the higher yields are exceptional and that they would not be maintained on repeated tapping. More recent information indicates that the earlier estimates of the amount of rubber furnished by the wild trees were too high and that the maximum annual yield from large trees does not usually exceed the lower figure mentioned above, viz. 10 lb. per tree.

With reference to the yield of rubber from cultivated Castilloa trees more definite information can be given, and it will be convenient to summarise the data under the different countries. It may be stated that on the whole the results of tapping plantations of Castilloa trees up to ten or twelve years old have been disappointing, the yields of rubber being much less than was anticipated. Individual trees and small groups of trees have given very

good results in many cases, but the average yield per tree obtained on tapping large plantations has been small.

MEXICO.—On the La Zacualpa No. 1 plantation about 400,000 trees, varying from four to twenty years old and including some scattered wild trees, have been tapped during recent years. The tapping has been done three times during the year, and the average yield of rubber from all the trees has been about 4 oz. per annum. Formerly the trees were not tapped until they were seven years old, and the average yield per tree was then between 7 and 8 oz. per annum. Several thousand twenty-year-old trees occur on the estate, and these have furnished an average annual yield of 2¼ lb. of rubber. The variety of tree cultivated at La Zacualpa is *Castilloa lactiflua*, which is one of the best rubber-yielding species.

The following results of single tappings of trees on estates in Mexico have been given by Smith:

No. of trees tapped.	Age.	Average yield of rubber per tree from single tapping.
	Years.	oz.
858	6–7	1·2
1,175	6–7	0·85
50,000	6–8	1
4,015	7–8	2·2

Pittier has recorded the opinion that the yields of rubber from cultivated Castilloa trees in Mexico were formerly much exaggerated. He states that trees which yield 500 grams (1·1 lb.) of rubber at one tapping are not uncommon, but that the number which only yield 50 grams is legion.

PANAMA.—In 1892 Weber conducted a series of experiments on Castilloa trees growing at the Las Cascadas plantation on the Isthmus of Panama in order to determine the yield of rubber. His results are summarised in the following table:

Age of trees.	Yield of latex.		Percentage of rubber in latex.	Yield of rubber.
Years.	lb.	oz.		oz.
6	1	13	26	7·5
7	2	5	26	9·6
8	3	1	29	14·2
11	5	3	31	25·7

The results for the trees eight and eleven years old are the means of a number of experiments, whilst the figures for the younger trees are the means of two trials. The results were considered to be rather below than above the average. Weber stated that the trees can be tapped safely twice a year, so that the annual yield of rubber would be double the above amounts.

Trinidad and Tobago.—(1) The Trinidad Department of Agriculture has published the results of experiments conducted on 200 Castilloa trees, which had not been previously tapped, growing on the Lure Estate, Tobago. Twenty of the trees were fourteen years old and from 60 to 86 in. in girth, whilst the remainder were ten years old and under, the majority of them ranging from 40 to 70 in. in girth. The trees were tapped by Smith's method to a height of about 20 ft.

The first series of experiments was conducted from April 6 to May 18, 1911, and an average yield of 5·12 oz. of dry rubber per tree was obtained. The trees were tapped a second time, using the same method, from August 7 to September 15, 1911, and furnished a further yield of 3·37 oz. of dry rubber per tree, making a total of 8·5 oz. per tree in the two tappings.

(2) The results of tapping 24,000 Castilloa trees, ten to twelve years old, in Tobago have been recorded by Smith. The trees were tapped three times during the year to a height of 6 ft. and furnished an average yield of 2⅓ oz. of dry rubber per tree. In the case of three groups of trees he also gives the yield from the first tapping, which is usually greater than that obtained from the subsequent tappings. :

No. of trees tapped.	Age.	Yield of rubber from first tapping.
	Years.	oz.
1,300	6–8	1
3,000	8–12	1
750	10–15	1·5

(3) Thirteen trees, eight to nine years old and from 33 to 69 in. in girth, were tapped to a height of 6 ft. by Smith's system, two tappings being made at an interval

of fifteen days. The average yield of dry rubber per tree was 3 oz. from the first tapping, and ¾ oz. from the second.

(4) The oldest Castilloa tree in Trinidad, estimated to be thirty years old, was tapped to a height of 40 ft. by Smith's system. Two tappings were made at an interval of one month and yielded 4 lb. 15 oz. of dry rubber, as shown in the following statement:

	Yield of latex.	Yield of dry rubber.		Percentage of dry rubber in latex.
	cc.	lb.	oz.	Per cent.
First tapping, Feb. 8, 1911	2,400	3	3	25·7
Second tapping, March 9, 1911	1,170	1	12	27·0

(5) A tree 57½ in. in girth and about fourteen years old was tapped by the double-herringbone system and yielded 9¾ oz. of dry rubber from the first tapping.

Jamaica.—The following results of tapping experiments made on Castilloa trees in Jamaica have been published by the Department of Agriculture in the Island:

(1) Twenty-one trees from eight to fourteen years old and with an average girth of 39 in. were tapped three times in nine months; the yield of rubber was as follows:

	lb.	oz.
1st tapping, May 1910	4	1
2nd ,, Sept. 1910	6	10
3rd ,, Jan. 1911	6	1
Total	16	12

The trees, therefore, yielded an average of 12·8 oz. of rubber in the nine months.

(2) Twenty-two trees, fourteen years old and with an average girth of 35 in., were tapped twice and furnished 8 lb. 12 oz. of rubber, equivalent to 6·4 oz. per tree.

(3) Two trees (*Castilloa guatemalensis*), about twenty-two years old and 48 in. in girth, were tapped five times with the following results:

		lb.	oz.
1st tapping . .	Dec. 1, 1909 .	1	5
2nd ,, . .	Dec. 28, 1909 .	1	0
3rd ,, . .	Feb. 19, 1910 .	0	9
4th ,, . .	Mar. 19, 1910 .	0	7½
5th ,, . .	Oct. 30, 1910 .	0	11
Total		4	0½

These two trees, therefore, yielded an average of 2 lb. of rubber in eleven months.

(4) A single tree (*Castilloa guatemalensis*), twenty-three years old and 86 in. in girth, gave 4 lb. 13 oz. of rubber at one tapping; this is the largest yield recorded in Jamaica from a single tree at one tapping.

(5) The following table summarises the results of other tapping experiments made on Castilloa trees in Jamaica by officers of the Agricultural Department:

No. of trees tapped.	Species.	Age. Years	Girth.	No. of tappings.	Yield of rubber per tree.
1 .	*C. guatemalensis*	8	48 in.	1	11 oz.
4 .	,,	10	—	1	3 ,,
3 .	,,	10	2 trees, 50 in. 1 tree, 37 in.	1	2 ,,
6 .	,,	10	—	1	2½ ,,
1 .	,,	12	72 in.	1	2 lb. 1 ,,
1 .	,,	12	84 ,,	1	1 ,, 11 ,,
1 .	,,	14	65 ,,	5*	2 ,, 9 ,,
1 .	,,	24	62 ,,	2	3 ,, 1 ,,
1 .	*C. elastica*	7	36 ,,	1	9 ,,
1 .	*C. costaricana*	10	36 ,,	1	7 ,,

Belgian Congo.—The following results of tapping experiments conducted on seven-year-old Castilloa trees growing in the Belgian Congo have been recorded:

No. of trees tapped.	Days tapped.	Yield of dry rubber. oz.
1	5	2⅓
1	5	2⅓
1	5	2¼
1	5	¾
1	8	2
1	8	2½

* Extending over a period of eight months.

No. of trees tapped.	Days tapped.	Yield of dry rubber.
		oz.
1	8	3½
1	9	3
1	13	11¼

Composition of Castilloa Rubber.—Castilloa rubber is somewhat variable in composition, as the percentage of resin fluctuates widely in different specimens. The following analyses, made at the Imperial Institute, will indicate the composition of specimens derived from various countries and prepared by different methods :

Country.	Description of rubber.	Composition of dry washed rubber.			
		Caoutchouc.	Resin.	Protein.	Ash.
		Per cent.	Per cent.	Per cent.	Per cent.
Mexico . .	Cone rubber made by Empire cream separator. Latex from wild trees .	93·7	5·4	0·8	0·1
,, . .	Cone rubber made by Empire cream separator . .	93·9	5·6	0·4	0·1
,, . .	Centrifugal sheets made by Smith's machine. Latex from cultivated trees . .	92·0	7·2	0·5	0·3
Trinidad and Tobago	Thick cake rubber from 7½-year-old trees. Latex creamed . .	47·4	51·9	0·5	0·2
,, ,, .	Thin cake rubber from 7½-year-old trees. Latex creamed	59·4	37·1	1·0	2·5
,, ,, .	Sheet rubber from 6-year-old trees .	76·5	20·7	0·6	2·2
,, ,, .	Block rubber from 17-year-old trees	74·4	22·8	0·7	2·1
,, ,, .	Sheet rubber .	61·6	37·6	0·4	0·4
,, ,, .	,, .	77·0	21·8	0·5	0·7
,, ,, .	,, .	83·5	15·6	0·4	0·5
,, ,, .	,, .	90·9	6·1	0·8	2·2
,, ,, .	Centrifugal sheet made by Smith's machine . .	70·8	28·6	0·5	0·1
Dominica . .	Sheet rubber .	84·7	9·4	3·8	2·1
St. Lucia . .	,, .	89·1	9·1	1·3	0·5
Southern India .	,, .	86·2	12·9	0·5	0·4
,, .	Sheet rubber from 6-year-old trees .	64·0	32·7	0·9	2·4
Zanzibar . .	Lump rubber .	77·5	20·6	1·5	0·4

CHAPTER XIV

THE ASSAM RUBBER TREE (*FICUS ELASTICA*, ROXB.) AND OTHER SPECIES OF FICUS

Species of Ficus.—A number of species of the genus Ficus, belonging to the natural order Urticaceae, furnish rubber or rubber-like material. Some species yield rubber of good quality, others give an inferior resinous rubber, whilst others again furnish hard, resinous products, resembling gutta percha more than rubber in physical properties, but containing a quantity of inferior caoutchouc and no gutta.

The best of the rubber-yielding species is *Ficus elastica*, Roxb., the well-known Assam rubber tree, but several other species such as *Ficus Rigo*, Bailey, and *Ficus Schlechteri*, Warb., both of which are natives of New Guinea, also yield good rubber.

None of the African species of Ficus produces rubber of first quality, and only one, *Ficus Vogelii*, Miq., is of importance as a source of inferior rubber. Several other species, however, such as *Ficus platyphylla*, Del., *Ficus bibracteata*, Warb., *Ficus trachyphylla*, Fenzl., and *Ficus utilis*, Sim, yield gutta-like products which are utilised for technical purposes.

Ficus elastica, Roxb.—This species is a native of south-eastern Asia and was first recorded from Assam. It occurs on the lower slopes of the Himalayas from Nepal eastwards, and thence extends southwards through Assam and Burma into the Malay Peninsula and the neighbouring islands.

It is found growing wild under a wide range of conditions of soil, temperature, and elevation, the essential features for its growth apparently being well-drained land and a very humid atmosphere. It is stated to occur in Assam up to 3,000 ft. on the Khasia Hills and in Upper

Burma on the hillsides up to 5,000 ft., thriving best in Assam up to 2,500 ft. and in Burma between 2,500 and 3,500 ft.

Ficus elastica is a very large evergreen tree which may attain a height of 120 ft. The branches give rise to numerous aerial roots which grow down to the soil and then thicken, forming subsidiary stems. The leaves are very characteristic, being dark green, large, and glossy. It is stated that at Charduar in Assam two varieties may be distinguished, one of which has much larger leaves than the other. The " fruits " are small, about the size of a pea, and contain from sixty to eighty minute seeds. In a wild state the trees usually develop as epiphytes on other trees, which are usually killed later by the enveloping roots.

The greater part of the rubber obtained from *Ficus elastica* is collected from wild plants, but the trees have been cultivated in India, at Kulsi and Charduar in Assam and on a smaller scale in Madras and Mysore, and also in the Malay Peninsula, Java, and Sumatra. The tree is known as " Rambong " in the Malay Peninsula, and " Karet " in Java.

Some years ago a considerable number of Rambong trees were planted in the Federated Malay States, but it has been found that the tree is much less satisfactory as a source of rubber than the Para tree, and it has consequently fallen into disfavour and is now no longer planted. On some estates the Rambong trees have been cut out and replaced by Para trees. The principal reasons for this adverse opinion are that the annual yield of rubber per acre from *Ficus elastica* trees is much less than from Para trees and that it diminishes rapidly when the trees are regularly tapped. In consequence of the latter fact the trees have to be rested periodically before they again yield well. In addition, the habit of growth of the trees renders them much more difficult to tap than Para trees and the latex is not so readily coagulated. For these reasons *Ficus elastica* cannot be recommended for cultivation in any district where the conditions are suitable for growing the Para tree, and even in Assam it seems doubtful from the results obtained on the Government plantations, whether the cultivation of *Ficus elastica* would prove remunerative unless under-

taken in conjunction with some other industry. In Java, however, large plantations of *Ficus elastica* have been established by the Forest Department, and are stated to have given satisfactory results, although the returns are much inferior to those from Para trees.

Cultivation.—*Ficus elastica* can be easily propagated from seeds or cuttings, or by layering. The plants are, however, usually raised from seed, which should be sown as soon as possible after collection. The seed is very small and is best sown in shallow boxes of rich soil which are covered with sheets of glass. Good, fresh seed will germinate in from five to fourteen days, and as soon as the seedlings are a few inches high they should be transferred to a well-drained nursery bed, being planted 12 to 18 in. apart. The plants may require to be protected from the sun for a short time, but shade should be dispensed with as soon as possible. When 5 ft. high the seedlings may be planted out, the roots being first pruned. In Assam it has been found difficult to protect the seedlings from wild animals if they are planted out at an early stage, and the plan has been adopted of transferring the young plants to a well-fenced nursery in the forest, where they remain until they are 10 to 12 ft. high and can be put out without risk.

The trees are planted in lines cut in the forest, or upon completely cleared land. In Assam lines 20 ft. wide are cleared at distances of 66 ft., and the trees are planted 66 ft. apart in the rows. Formerly the lines were cut east and west, but latterly they have been made north and south in order to shade the plants from the afternoon sun. On cleared land the trees are planted from 35 to 50 ft. apart.

Ficus elastica is a surface feeder, and it is customary in Assam to plant the trees on prepared mounds of soil which are usually made 4 ft. high, 10 ft. in diameter at the base, and 4 ft. at the top. After the young trees are planted, the mounds are covered with grass in order to prevent the roots from being scorched.

Attempts to grow the trees as epiphytes, by depositing seed on other trees in imitation of the natural method of propagation, have not been successful in Assam.

Rate of Growth.—The size attained by cultivated *Ficus elastica* trees is shown by the following table giving the

average measurements of trees at the Charduar plantation in Assam :

Age of trees. Years.	Average height. ft.	Average girth. ft.
1	7·36	0·26
2	9·98	0·38
3	14·17	0·64
4	18·29	0·95
5	22·50	1·39
10	43·04	4·48
15	60·71	8·52
20	74·98	12·93
24	85·00	23·16

The average annual increase in the height of the trees at Charduar during twenty-four years was about 3·38 ft. and in girth 0·99 ft.

Collection of the Rubber.—In Assam and Burma the latex of *Ficus elastica* does not flow sufficiently freely to be collected in bulk. When incisions are made a slight flow of latex occurs, but after two or three minutes this ceases and the latex then simply fills the cuts and there coagulates. In order to obtain the rubber in these circumstances a number of transverse cuts are usually made on the stems and branches by means of a V-shaped gouge. The cuts are made 18 in. apart and extend about half-way round the stem or branch. The latex which flows from the cuts either runs down the stem or, in the case of incisions made in the branches, falls to the ground, and is there received on small bamboo mats placed to catch it. These mats are moved about as the tapping proceeds, and the latex is allowed to coagulate upon them, thus forming a cake of rubber which is subsequently stripped off. The rubber which coagulates in the cuts and on the stem is allowed to remain for two or three days, and is then collected in the form of scrap, which is first cleaned by hand picking, then dried, and finally pressed into blocks. The "mat" rubber is treated in a similar way.

Another method of tapping which has been tried in Cachar consists in making a series of transverse cuts, at least 1½ in. apart, with a chisel ½ to ¾ in. wide. These

cuts are arranged in vertical rows, 6 in. apart, and a cup is fixed at the base of each row. In trials of this method during the dry season (November to March) it was found that two-thirds of the total yield of rubber was obtained from the latex collected in the cups, whilst the remainder coagulated on the stem.

In Java the latex of *Ficus elastica* quickly coagulates spontaneously on the stems, and until recently the whole of the rubber was collected in the form of scrap which was made into balls. In 1911, however, machinery was introduced for treating the scrap rubber, and some of it is now prepared in the form of crêpe or block.

In the Malay Peninsula the latex of *Ficus elastica* usually flows much more freely than in Assam and Burma and can be easily collected in bulk. A number of different methods of tapping have been tried, including herringbone incisions, V incisions, and vertical incisions, as well as several pricking systems. A method of making the incisions which has been recommended is to cut shallow grooves in the bark in the first instance and then to liberate the latex by means of a sharp thin-bladed knife or by a pricker.

Coagulation of the Latex.—It is a curious fact that when the latex of *Ficus elastica* flows sufficiently freely to be collected in bulk it does not readily coagulate, whereas in other cases it coagulates so quickly on exposure to the air that the rubber can only be obtained in the form of scrap.

The latex is not affected by the addition of acetic acid, and methods of churning which have been suggested are not very successful. It can, however, be coagulated by boiling, but this method is not very satisfactory, as the rubber only separates slowly, and the heating must consequently be continued for a long time. Burgess recommends the use of tannic acid as the best coagulant for *Ficus elastica* latex, and has proposed the following process. The latex, which should not be diluted with water, is warmed to 40° C., and a solution of tannic acid of known strength is then added until there is 1 per cent. of tannic acid in the latex. Thus, using a 20 per cent. solution of tannic acid, one part of the solution would be added to nineteen parts of latex. The latex is then gently churned, avoiding violent agitation, and in one or

two minutes it sets to a cream and complete coagulation occurs.

It is stated that the latex may be conveniently coagulated by adding a 2 per cent. solution of formalin and allowing it to stand.

Yield of Rubber.—The following figures showing the amount of rubber obtained at the Charduar and Kulsi plantations in Assam will illustrate the yield of rubber furnished by the trees in that country:

	Area tapped.	No. of trees tapped.	Yield of rubber.		
			Total.	Per tree.	Per acre.
	Acres.		lb.	lb.	lb.
Charduar:					
1907–8 . .	642	8,265	8,346	1	13
1908–9 . .	417	4,734	7,560	1·6	18·1
1909–10 . .	348	5,542	12,971	2·3	37·3
1910–11 . .	336	4,327	9,087	2·1	27·0
Kulsi:					
1907–8 . .	88	2,087	4,083	2	46
1908–9 . . .	66	3,955	2,573	0·65	39
1909–10 . .	88	1,477	3,240	2·2	36·8
1910–11 . .	66	—	—	0·9	52

The trees at Kulsi are planted much closer than those at Charduar, and hence the yields per acre are higher.

In Cachar a number of trees tapped by making numerous small cuts with a chisel, as described on p. 230, gave the following results:

Eight trees planted in 1882 were tapped in 1905–6 and gave an average yield of 6 lb. of rubber per tree. The same trees tapped in 1906–7 gave an average of 5 lb. per tree, the individual yields varying from 2½ to 10 lb.

Four younger trees, planted in 1899–90, gave an average of about 2 lb. of rubber in 1905–6 and 2¼ lb. in 1906–7, the individual yields in the latter year being 1¼, 2¼, 2½, and 3½ lb.

A four-year-old *Ficus elastica* in Klang, Federated Malay States, was tapped twice during a year and yielded 5 oz. of rubber from the first tapping and 2¾ oz. from the second.

It is stated that in Java *Ficus elastica* can be tapped in the sixth year, and that the amount of rubber obtained increases with the age of the trees.

The Forest Service in Java had 12,738 acres planted

with *Ficus elastica* in 1911, and the yield of rubber obtained therefrom was 30,000 kilograms, *i.e.* about 2·5 kilograms (5·5 lb.) per acre. The yield has increased during the last few years, and it is estimated that in 1916 it will amount to 258,000 kilograms (about 44 lb. per acre).

Tapping experiments conducted in Java at Pamanoekan and Tjiasem on 5,200 trees gave the following results :

Age of trees. Years.	Yield of rubber from 5,200 trees. kilograms.
14	2,500
15	2,247
16	686
17	Not tapped
18	1,500
19	2,772
20	2,718
21	Not tapped
22	Not tapped
23	1,450

The diminution which takes place in the yield of rubber from *Ficus elastica* trees on continued tapping is shown by the following results obtained in Assam :

Twenty-one selected dominant trees at Charduar were tapped three years in succession and furnished 46 lb., 48 lb., and 9 lb. of rubber in the first, second, and third year respectively.

Two groups of fifty trees each were tapped three years in succession by reopening the old incisions in one group and by making fresh incisions in the other. The following results were obtained :

	1st year.		2nd year.		3rd year.	
	lb.	oz.	lb.	oz.	lb.	oz.
50 trees, incisions reopened	55	7	42	4	14	8
50 trees, new incisions made	43	0	35	13	24	1

Experiments in other countries have given similar results, and it seems probable that *Ficus elastica* trees cannot be tapped regularly every year, but require to be periodically rested.

Composition of the Rubber.—The rubber of *Ficus elastica* is rather variable in composition owing to the great differences which occur in the amount of resin, as will be seen from the following analyses, made at the Imperial Institute, of specimens from different countries:

Country.	Description of rubber.	Caoutchouc.	Resin.	Protein.	Insoluble matter.	Ash.
India:		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Charduar	Tree rubber	77·5	19·3	1·5	1·7	0·5
Kulsi	,,	78·6	19·1	0·9	1·4	0·5
,,	Mat rubber	81·9*	16·2	—	1·9	1·9
Madras (Mukkie)	Scrap	67·9	28·4	0·9	2·8	0·5
,, ,,	Biscuit	74·3	23·6	1·0	1·1	1·7
,, (Parlakimedi)	Cake	88·6	8·1	1·4	1·9	0·5
Gold Coast	Scrap	81·3	11·8	2·6	4·3	1·1
Southern Nigeria	Biscuits	89·6	8·4	0·8	—	1·2
,, ,,	,,	92·3	6·6	0·8	—	0·3
,, ,,	,,	93·7	5·4	0·7	—	0·2

Ficus Vogelii, Miq.—*Ficus Vogelii* is the most important of the African species of Ficus so far as the production of rubber is concerned. The rubber which it furnishes is, however, of inferior quality on account of its resinous nature and its poor physical properties.

Ficus Vogelii is a tree from 20 to 50 ft. in height and from 8 to 20 in. in girth, with large elliptical or obovate-oblong leaves, 6 to 12 in. long and 4 to 6 in. broad. The brownish receptacles ("fruits") are spherical, from $\frac{1}{3}$ to $\frac{1}{2}$ in. in diameter, and usually occur in pairs in the leaf axils or in clusters of four to six below the hairy terminal buds at the ends of the branches. It is said that the trees can be readily propagated from cuttings, and that they are easily cultivated.

Chevalier states that *Ficus Vogelii* is found in the forests of French West Africa both as an epiphyte (growing upon another tree) or as a distinct tree, and that according to the natives the epiphytic trees yield the most rubber.

The tree occurs throughout West Africa from Senegal to the mouth of the Congo, and is especially abundant in the coastal regions, where it occurs in the swampy forests. It is also found in Northern Nigeria.

The trees are not generally exploited in West Africa by

* Including protein.

the rubber collectors, except in certain districts where its latex appears to be added to Funtumia latex in the preparation of "lump" rubber. It is stated that this practice is followed in parts of Sierra Leone, Liberia, and the Ivory Coast. In Northern Nigeria, however, the rubber of *Ficus Vogelii* is prepared separately by the natives and the product appears on the market as "Niger balata."

The natives obtain the latex either by tapping the trees, or by felling them and making numerous annular incisions in the trunk and branches.

The rubber is usually prepared by allowing the latex to stand until it coagulates, or by boiling the latex after the addition of an acid juice. Coagulation can also be brought about by immersing the vessel containing the latex in boiling water or by diluting the latex with an equal quantity of water, allowing it to stand until it creams, and then submitting the separated cream of rubber globules to pressure.

Ficus Vogelii is stated to give a large yield of latex and rubber. A tree thirteen years old growing in Lagos, which was tapped during the dry season, yielded 3 quarts of latex without suffering injury, and Chevalier records that a single tree will yield as much as 10 kilograms (22 lb.) of rubber. In the Gold Coast single trees have furnished 2 to 10 lb. of rubber.

Five-year-old trees in the Belgian Congo gave an average yield of 2½ oz. of dry rubber per tree from four days' tapping.

It has been stated already that the rubber of *Ficus Vogelii* is of very resinous character, and the following analyses, made at the Imperial Institute, of specimens from the Gambia, Gold Coast, and Northern Nigeria will indicate its usual composition. The figures express the percentage composition of the dry material.

	Gambia.			Gold Coast.				Northern Nigeria.	
	(1)	(2)	(3)	(1)	(2)	(3)	(4)	(1)	(2)
Caoutchouc	60·6	65·9	65·3	52·4	61·1	66·2	65·5	59·5	49·2
Resin	35·4	31·8	29·9	44·4	35·9	31·6	30·9	36·6	47·7
Protein	1·5	1·4	1·0	2·3	1·7	1·9	2·5	1·8	2·4
Insoluble matter	2·5	0·9	3·8	—	—	—	—	2·1	—
Ash	0·6	1·4	0·4	0·9	1·3	0·3	1·1	1·7	0·7

It will be seen that the percentage of caoutchouc in the different specimens ranges from about 50 to 66 per cent. and of resin from about 30 to 48 per cent. Owing to the large amount of resin present, the rubber is usually deficient in elasticity and inclined to be soft and sticky. It can, however, be utilised for mixing purposes in rubber manufacture, and a definite demand now exists for the "Niger balata," which is regularly quoted on the Liverpool market. Its value in Liverpool on July 1, 1913, was 1*s.* 7*d.* to 1*s.* 8*d.* per lb., with lump Funtumia rubber at 1*s.* 4*d.* to 1*s.* 9*d.* per lb. and fine hard Para at 3*s.* 10*d.* per lb.

African Species of Ficus yielding Gutta-like Products.—The latex of a number of the African species of Ficus furnishes a hard resinous product, possessing in some cases a fair amount of tenacity and exhibiting a superficial resemblance to gutta percha. The material, however, contains no gutta, the characteristic constituent of gutta percha, but a quantity of caoutchouc, and is, therefore, more allied to rubber than to gutta percha. The principal species which have been reported to yield such products in West Africa are *Ficus platyphylla*, Delile, *Ficus bibracteata*, Warb., and *Ficus trachyphylla*, Fenzl.

All three species occur in Northern Nigeria, and during recent years considerable quantities of the product have been exported from that country under the name of "Niger gutta." It is a hard reddish-brown mass which is obtained by boiling the latex, and is known locally as "red Kano rubber." It is used for mixing purposes in rubber manufacture, and is now regularly quoted on the Liverpool market. Its value on July 1, 1913, was 7½*d.* to 8*d.* per lb. in Liverpool. The percentage composition of the product is shown by the following analyses made at the Imperial Institute:

	"Niger gutta."			*Ficus platyphylla* from the Sudan.	
	(1)	(2)	(3)	(1)	(2)
Moisture	2·5	8·9	3·7	4·4	8·8
Caoutchouc	15·1	9·8	13·2	24·5	18·8
Resin	74·9	75·2	78·5	67·2	64·1
Insoluble matter	7·5	6·1	4·6	3·9	8·3
Ash	3·5	4·3	1·9	1·1	3·6

Another species of Ficus occurring in Portuguese East Africa and Natal also furnishes a similar product. This tree has been described as *Ficus utilis*, Sim, and is known as "Mpai" in Zululand. A sample of the product examined at the Imperial Institute had the following composition :

	Material as received. Per cent.	Composition of dry material. Per cent.
Moisture	28·4	—
Caoutchouc . . .	19·6	27·4
Resin	49·9	69·6
Insoluble matter . .	2·1	3·0
Ash	0·8	1·1

This product would realise about the same price as the "Niger gutta."

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